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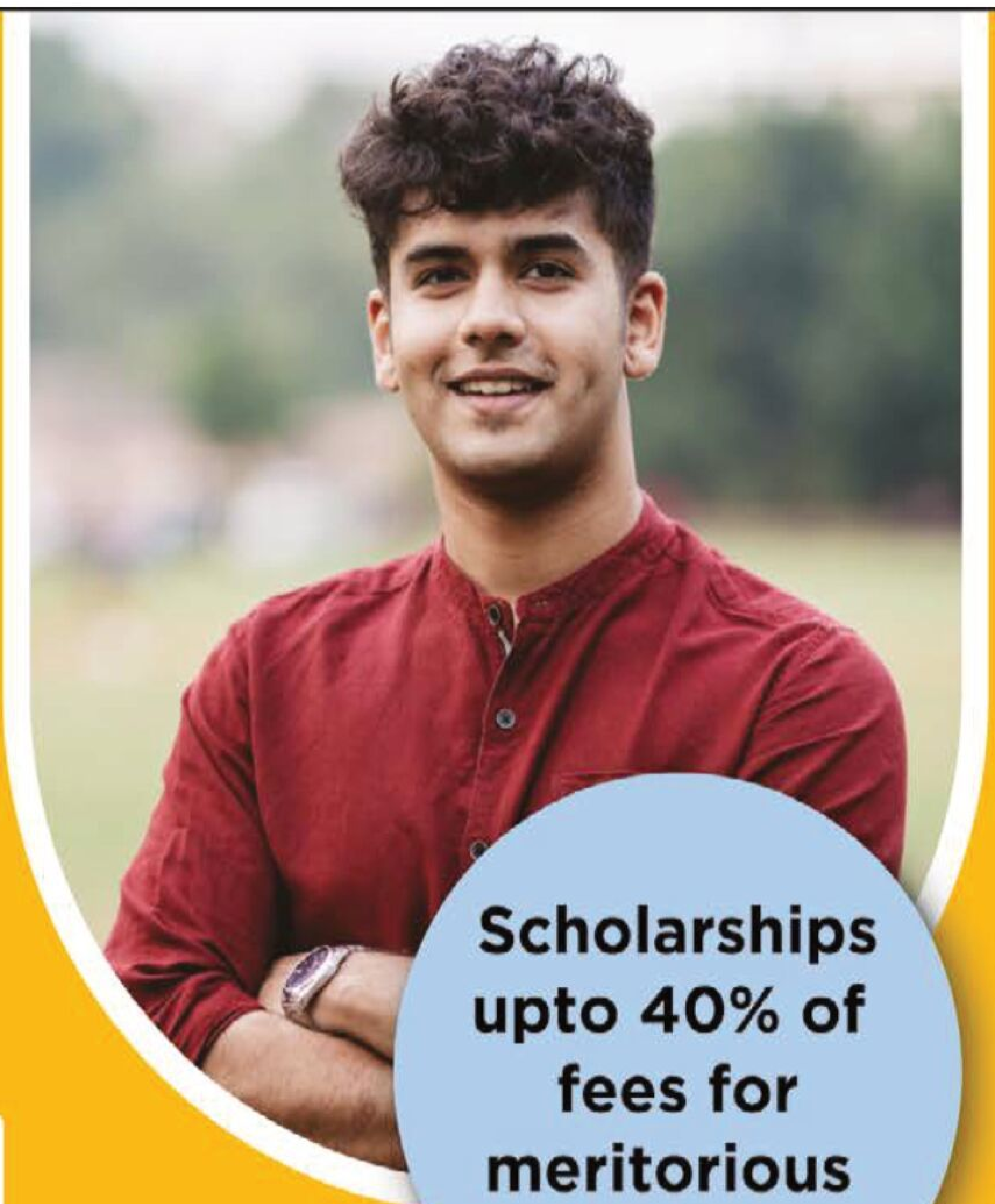

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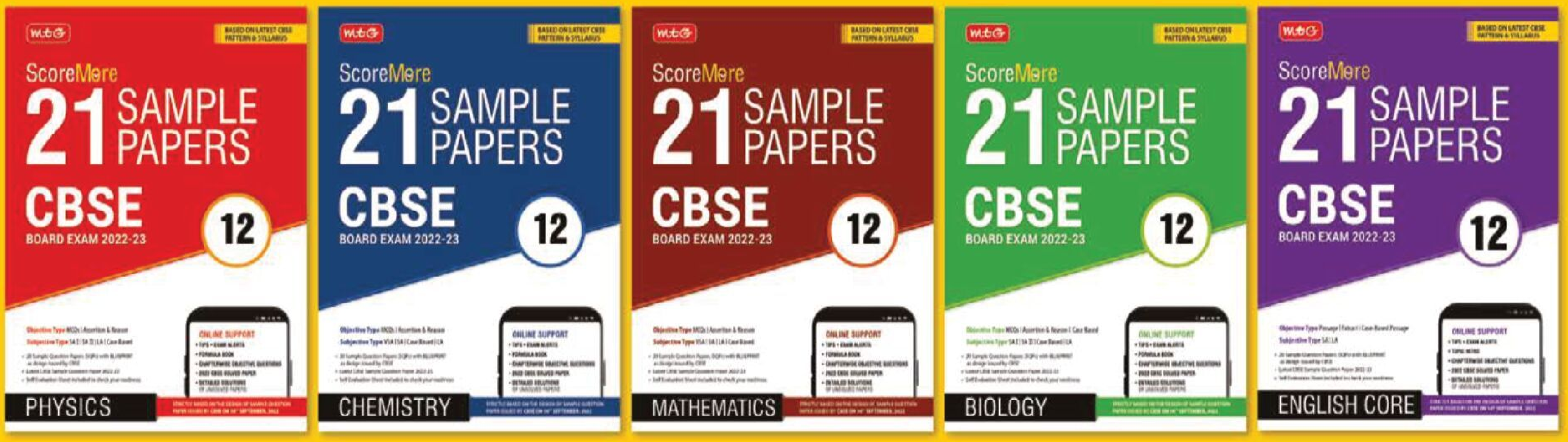
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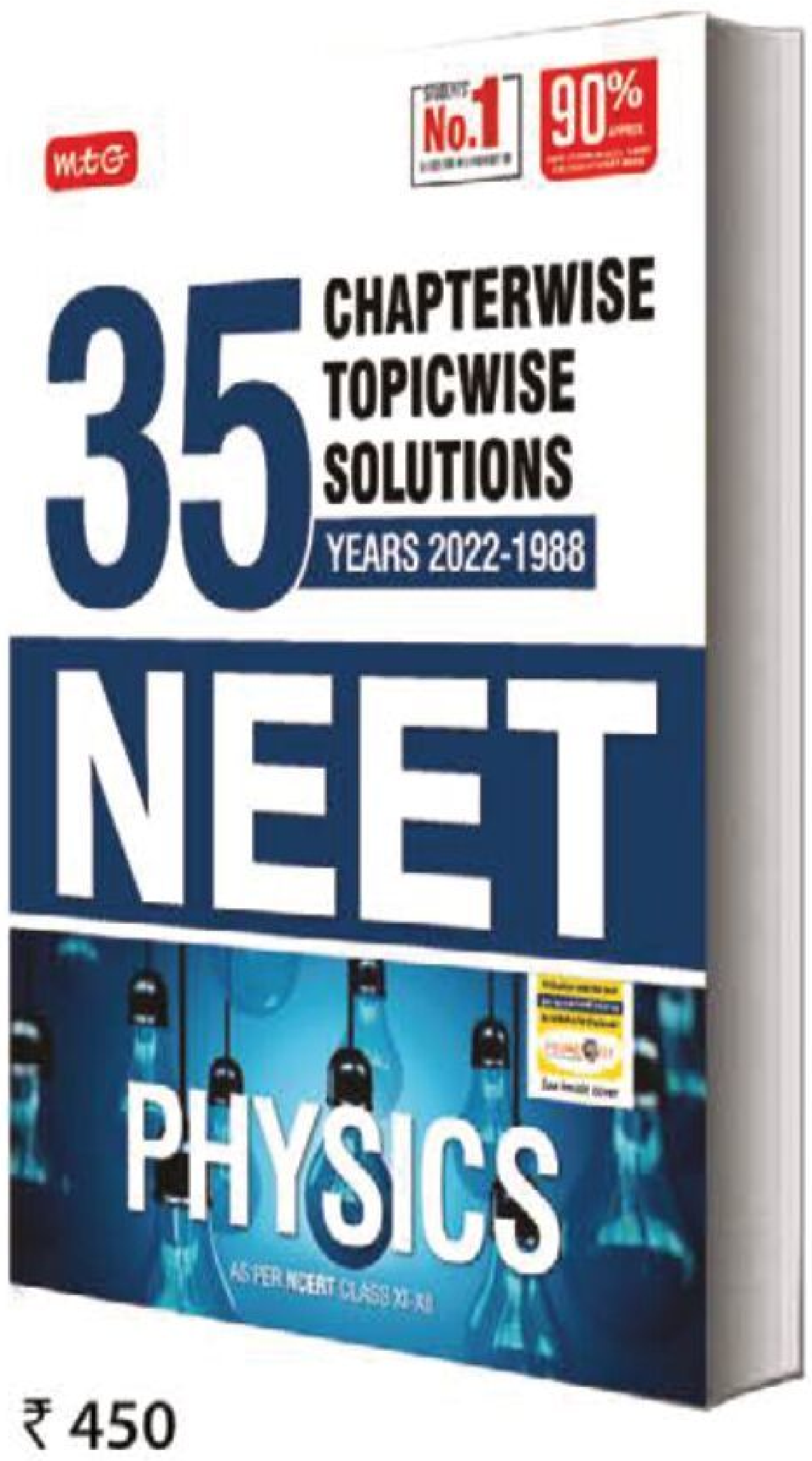
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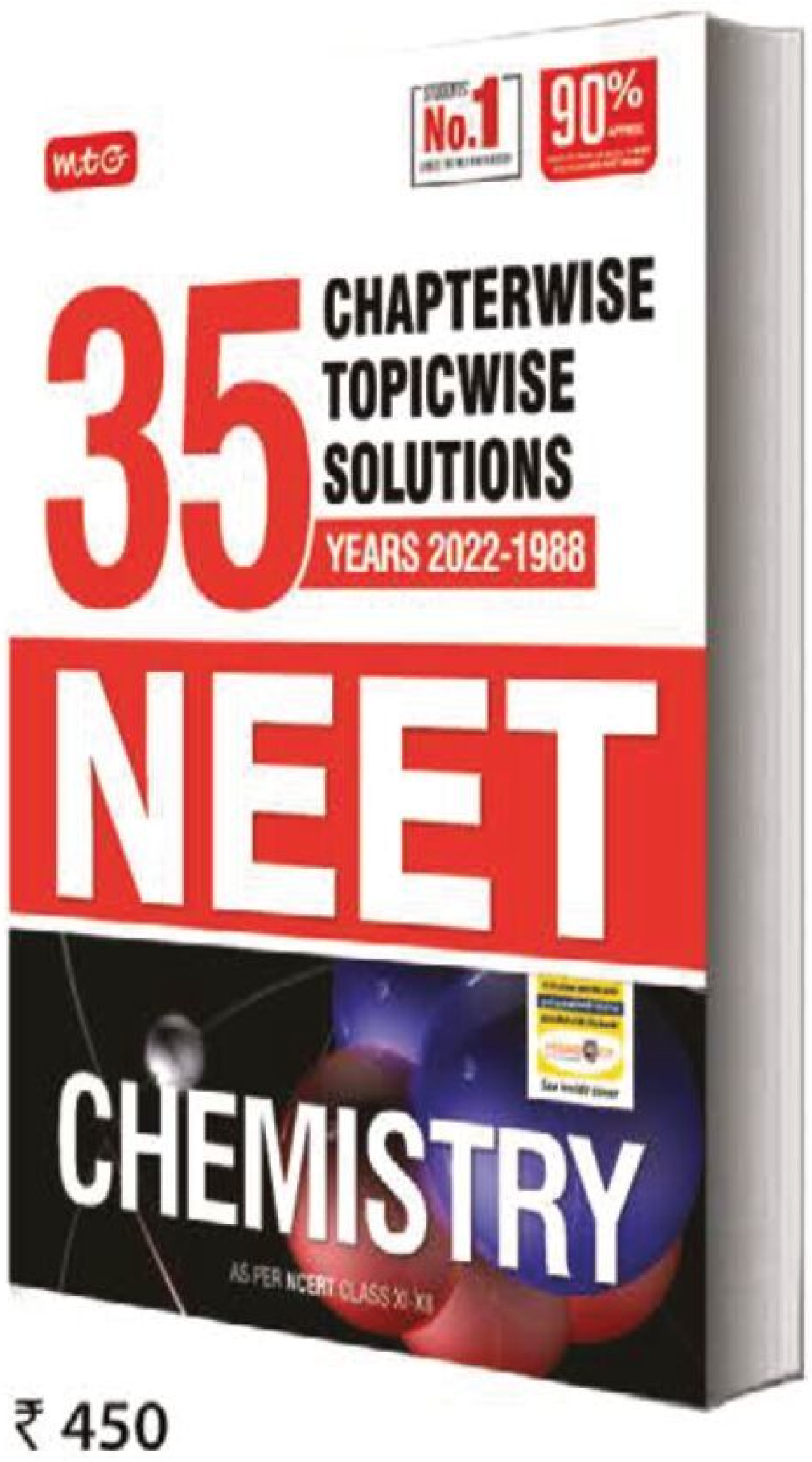
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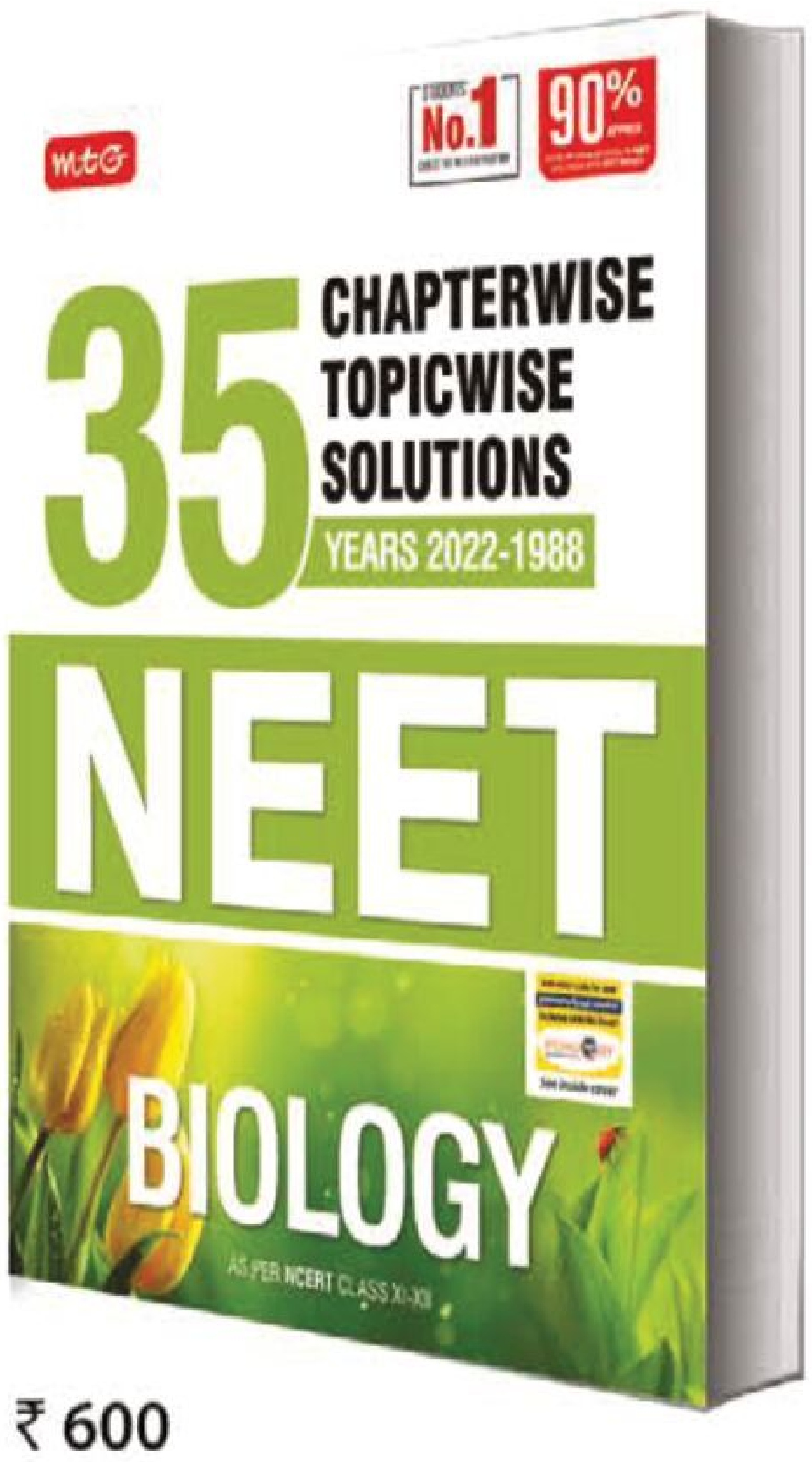
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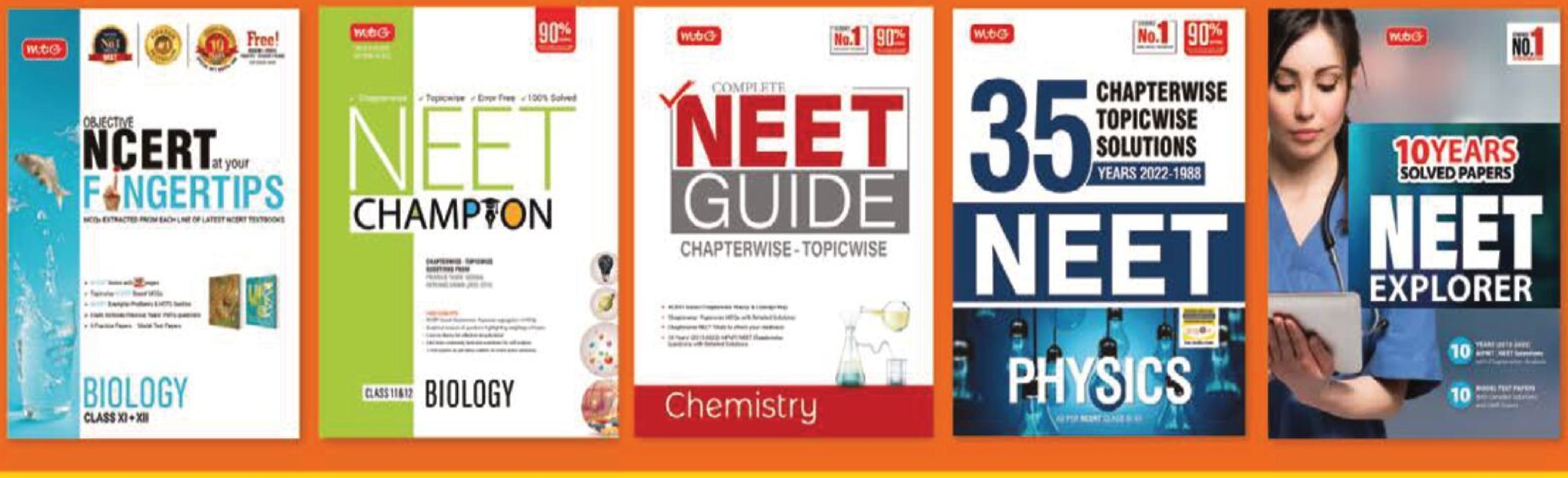
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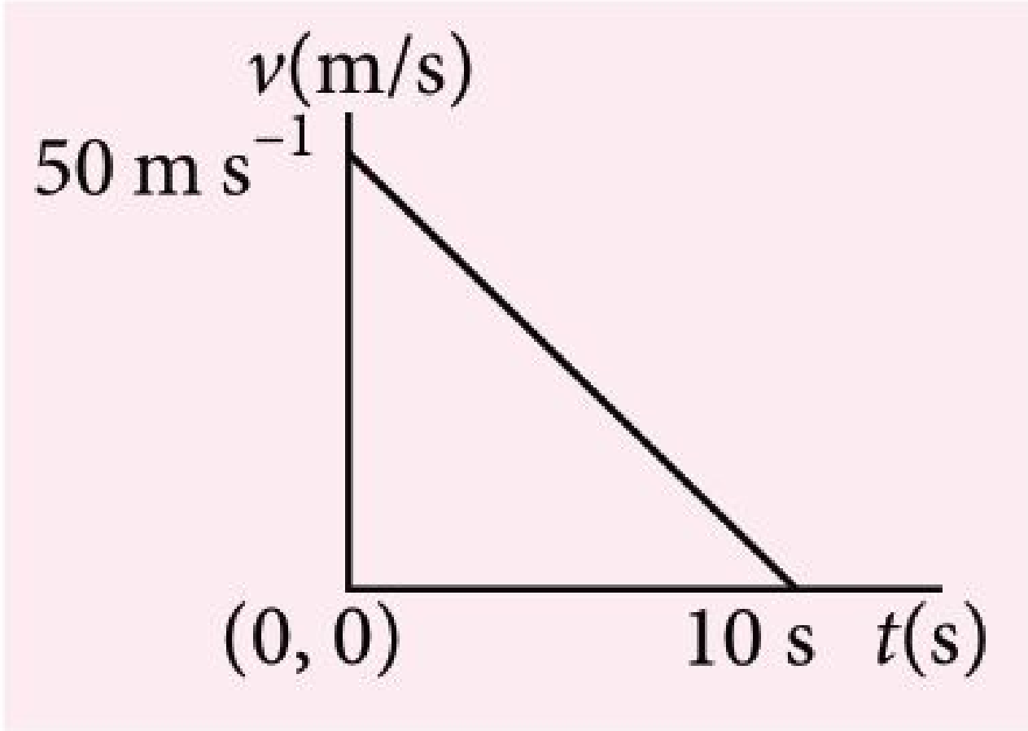
PRACTICE PAPER 2023
JEE MAIN

Exam Dates
Session-1
24, 25, 27, 28, 29, 30, 31 January 2023
Session-2
06, 08, 10, 11, 12 April 2023

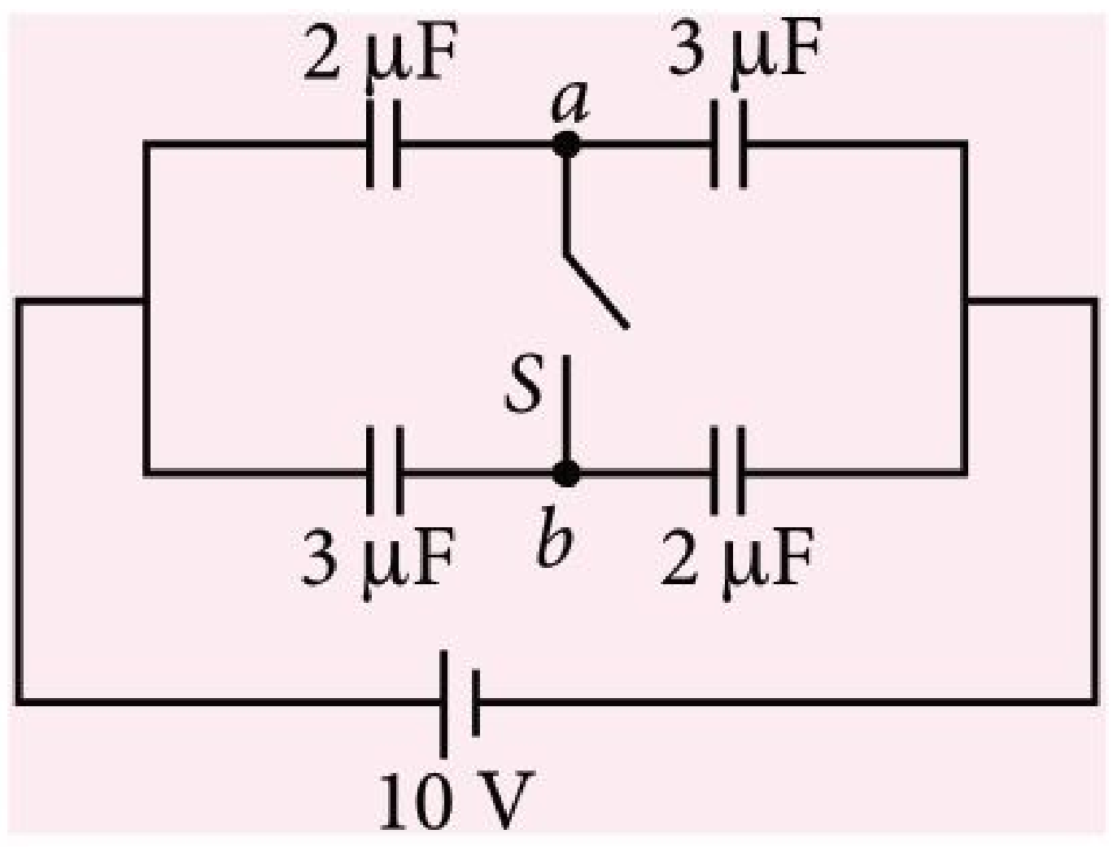
SECTION-A (MULTIPLE CHOICE QUESTIONS)

1. Velocity-time graph for a body of mass 10 kg is shown in figure. Work-done on the body in first two seconds of the motion is



(a) – 9300 J (b) 12000 J
(c) – 4500 J (d) – 12000 J

2. In figure is shown a system of four capacitors connected across a 10 V battery. Charge that will flow from switch *S* when it is closed is



(a) 5 μC from *b* to *a* (b) 20 μC from *a* to *b*
(c) 5 μC from *a* to *b* (d) zero

3. A power transmission line feeds input power at 2300 V to a step-down transformer with its primary windings having 4000 turns. The output power is delivered at 230 V by the transformer. If the current in the primary of the transformer is 5 A and its efficiency is 90%, the output current would be
(a) 25 A (b) 50 A (c) 45 A (d) 35 A

4. In a region, steady and uniform electric and magnetic fields are present. These two fields are parallel to each other. A charged particle is released from rest in this region. The path of the particle will be a
(a) circle (b) helix
(c) straight line (d) ellipse

5. A light ray enters a solid glass sphere of refractive index $\mu = \sqrt{3}$ at an angle of incidence 60°. The ray is both reflected and refracted at the farther surface of the sphere. The angle (in degrees) between the reflected and refracted rays at this surface is
(a) 60 (b) 30 (c) 90 (d) 45

6. The time period of a satellite of earth is 5 hour. If the separation between the earth and the satellite is increased to 4 times the previous value, the new time period will become
(a) 10 hour (b) 80 hour
(c) 40 hour (d) 20 hour

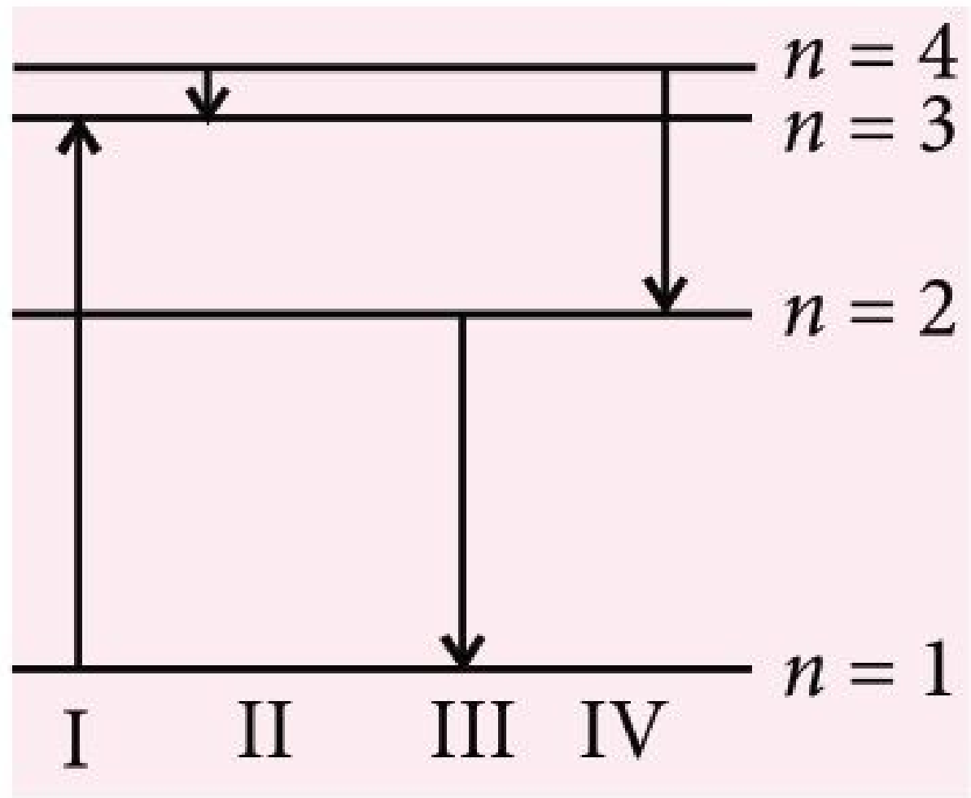
7. Two identical conducting spheres *A* and *B*, carry equal charge. They are separated by a distance much larger than their diameters, and the force between them is *F*. A third identical conducting sphere, *C*, is uncharged. Sphere *C* is first touched to *A*, then to *B*, and then removed. As a result, the force between *A* and *B* would be equal to
(a) $\frac{3F}{8}$ (b) $\frac{F}{2}$ (c) $\frac{3F}{4}$ (d) F

8. A source of light is placed in front of a screen. Intensity of light on the screen is *I*. Two polaroids P_1 and P_2 are so placed in between the source of light and screen that the intensity of light on screen is *I*/2. By what angle should P_2 be rotated so that intensity of light on the screen becomes $\frac{3I}{8}$.?
(a) 30° (b) 45° (c) 90° (d) 180°

9. The nuclear activity of a radioactive element become $(1/8)^{th}$ of its initial value in 30 years. The half-life of radioactive element is
(a) 5 years (b) 2 years (c) 8 years (d) 10 years

10. If force (*F*), length (*L*) and time (*T*) are taken as the fundamental quantities. Then what will be the dimension of density?
(a) $[FL^{-4}T^2]$ (b) $[FL^{-3}T^3]$
(c) $[FL^{-3}T^2]$ (d) $[FL^{-5}T^2]$

11. The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy?



(a) I (b) II (c) III (d) IV

12. Two spheres of the same material have radii 1 m and 4 m and temperatures 4000 K and 2000 K respectively. The ratio of the energy radiated per second by the first sphere to that by the second is

(a) 1 : 1 (b) 16 : 1 (c) 4 : 1 (d) 1 : 9

13. de-Broglie wavelength of an electron accelerated by a voltage of 50 V is close to ($|e| = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ J s)

(a) 0.5 Å (b) 1.2 Å (c) 1.7 Å (d) 2.4 Å

14. The electrical conductivity of a semiconductor increases when electromagnetic radiation of wavelength shorter than 2480 nm is incident on it. The band gap in (eV) for the semiconductor is

(a) 0.5 eV (b) 0.7 eV (c) 1.1 eV (d) 2.5 eV

15. Match the column.

Column-I		**Column-II**	
(A)	MI of the rod (length L, mass M, about an axis ⊥ to the rod passing through the midpoint)	(i)	$\frac{8ML^2}{3}$
(B)	MI of the rod (length L, mass $2M$, about an axis ⊥ to the rod passing through one of its end)	(ii)	$\frac{ML^2}{3}$
(C)	MI of the rod (length $2L$, mass M, about an axis ⊥ to the rod passing through one of its end)	(iii)	$\frac{ML^2}{12}$
(D)	MI of the rod (length $2L$, mass $2M$ about an axis ⊥ to the rod passing through one of its end)	(iv)	$\frac{2ML^2}{3}$

Choose the correct answer from the options given below.

(a) (A) - (iii), (B) - (iv), (C) - (ii), (D) - (i)
(b) (A) - (ii), (B) - (iii), (C) - (i), (D) - (iv)
(c) (A) - (iii), (B) - (iv), (C) - (i), (D) - (ii)
(d) (A) - (ii), (B) - (i), (C) - (iii), (D) - (iv)

16. Two full turns of the circular scale of a screw gauge cover a distance of 1 mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of – 0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is

(a) 3.38 mm (b) 3.32 mm
(c) 3.73 mm (d) 3.67 mm.

17. The correct match between the entries in column I and column II are

I **Radiation**		**II** **Wavelength**	
(A)	Microwave	(i)	100 m
(B)	Gamma rays	(ii)	10^{-15} m
(C)	A.M. radio waves	(iii)	10^{-10} m
(D)	X-rays	(iv)	10^{-3} m

(a) (A)-(ii), (B)-(i), (C)-(iv), (D)-(iii)
(b) (A)-(i), (B)-(iii), (C)-(iv), (D)-(ii)
(c) (A)-(iii), (B)-(ii), (C)-(i), (D)-(iv)
(d) (A)-(iv), (B)-(ii), (C)-(i), (D)-(iii)

18. A compound microscope consists of an objective lens of focal length 1 cm and an eye piece of focal length 5 cm with a separation of 10 cm. The distance between an object and the objective lens, at which the strain on the eye is minimum is $\frac{n}{40}$ cm. The value of n is

(a) 30 (b) 70 (c) 50 (d) 90

19. A point mass oscillates along the x-axis according to the law $x = x_0 \cos(\omega t - \pi/4)$. If the acceleration of the particle is written as $a = A\cos(\omega t + \delta)$, then

(a) $A = x_0\omega^2, \delta = 3\pi/4$ (b) $A = x_0, \delta = -\pi/4$
(c) $A = x_0\omega^2, \delta = \pi/4$ (d) $A = x_0\omega^2, \delta = -\pi/4$

20. A uniform wire of length l and radius r has a resistance of 100 Ω. It is recast into a wire of radius $\frac{r}{2}$. The resistance of new wire will be

(a) 400 Ω (b) 100 Ω (c) 200 Ω (d) 1600 Ω

SECTION-B (NUMERICAL TYPE QUESTIONS)

Attempt any 5 questions out of 10.

21. A particle is moving along the x-axis with its coordinate with time t given by $x(t) = 10 + 8t - 3t^2$. Another particle is moving along the y-axis with its coordinate as a function of time given by $y(t) = 5 - 8t^3$. At $t = 1$ s, the speed of the second particle measured in the frame of the first particle is given as $\sqrt{v}$. Then v (in m/s) is _______.

22. The energy dissipated by a resistor is 10 mJ in 1 s when an electric current of 2 mA flows through it. The resistance is _____ Ω. (Round off to the nearest integer)

23. A small bob tied at one end of a thin string of length 1 m is describing a vertical circle so that the maximum and minimum tension in the string are in the ratio 5 : 1. The velocity of the bob at the highest position is ______ m/s. (Take $g = 10$ m/s^2)

24. Orange light of wavelength 6000×10^{-10} m illuminates a single slit of width 0.6×10^{-4} m. The maximum possible number of diffraction minima produced on both sides of the central maximum is _______.

25. The frequency of a car horn encountered a change from 400 Hz to 500 Hz, when the car approaches a vertical wall. If the speed of sound is 330 m s^{-1}, then the speed of car is ______ km h^{-1}.

26. A travelling microscope is used to determine the refractive index of a glass slab. If 40 divisions are there in 1 cm on main scale and 50 Vernier scale divisions are equal to 49 main scale divisions, then least count of the travelling microscope is : ________ $\times 10^{-6}$ m.

27. A circular disc of mass M and radius R is rotating about its axis with angular speed ω_1. If another stationary disc having radius $R/2$ and same mass M is dropped coaxially onto the rotating disc. Gradually both discs attain constant angular speed ω_2. The energy lost in the process is p% of the initial energy. Value of p is _________.

28. An external pressure P is applied on a cube at 0°C so that it is equally compressed from all sides. K is the bulk modulus of the material of the cube and α is its coefficient of linear expansion. Suppose we want to bring the cube to its original size by heating. The temperature should be raised by $\frac{P}{n\alpha K}$, where the value of n is _____.

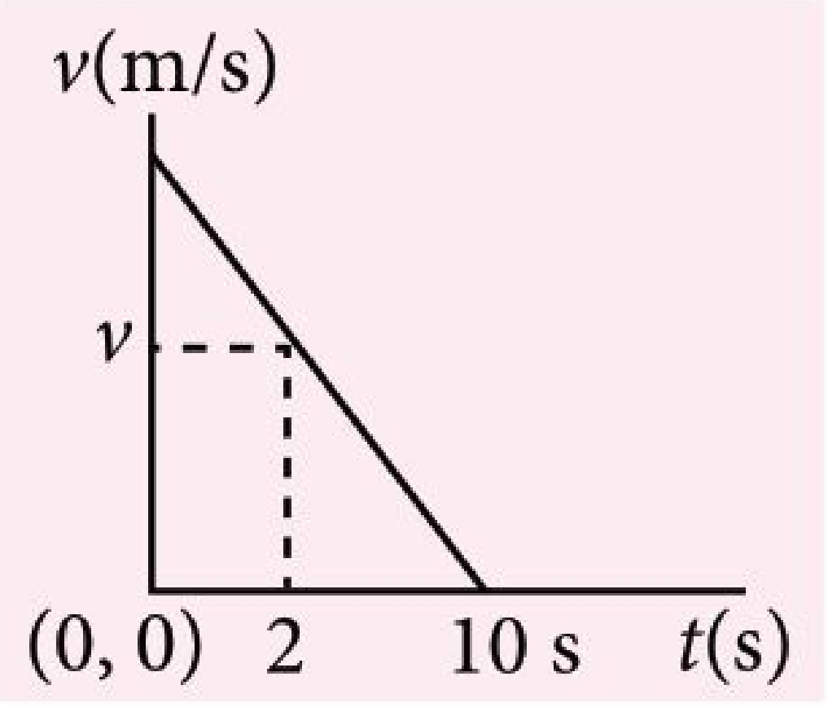
29. A long solenoid with 1000 turns/m has a core material with relative permeability 500 and volume 10^3 cm^3. If the core material is replaced by another material having relative permeability of 750 with same volume maintaining same current of 0.75 A in the solenoid, the fractional change in the magnetic moment of the core would be approximately $(x/499)$. Find the value of x.

30. The maximum and minimum amplitude of an amplitude modulated wave is 16 V and 8 V respectively. The modulation index for this amplitude modulated wave is $x \times 10^{-2}$. The value of x is ________.

SOLUTIONS

1. **(c) :** Here, $m = 10$ kg, $t = 2$ s and $u = 50$ m s^{-1}

At $t = 0$ s, $a = \dfrac{\Delta v}{\Delta t} = \dfrac{50-0}{0-10} = -5$ m s^{-2}



Speed of the body at $t = 2$ s,
$v = u + at$
$= 50 + (-5) \times 2$
$= 40$ m s^{-1}

Using work-energy theorem,
Work done on the body = change in kinetic energy of the body

$$\Delta W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2}\times 10\times 40^2 - \frac{1}{2}\times 10\times 50^2$$

$= 5 \times (40 - 50)(40 + 50) = -4500$ J

2. **(a)**

3. **(c) :** $\varepsilon_p = 2300$ V, $N_p = 4000$
$\varepsilon_s = 230$ V, $I_p = 5$ A, $\eta = 90\% = 0.9$, $I_s = ?$

$$\eta = \frac{P_o}{P_i} = \frac{\varepsilon_s I_s}{\varepsilon_p I_p}$$

$$I_s = \frac{\eta\,\varepsilon_p I_p}{\varepsilon_s} = \frac{0.9 \times 2300 \times 5}{230} = 45 \text{ A}$$

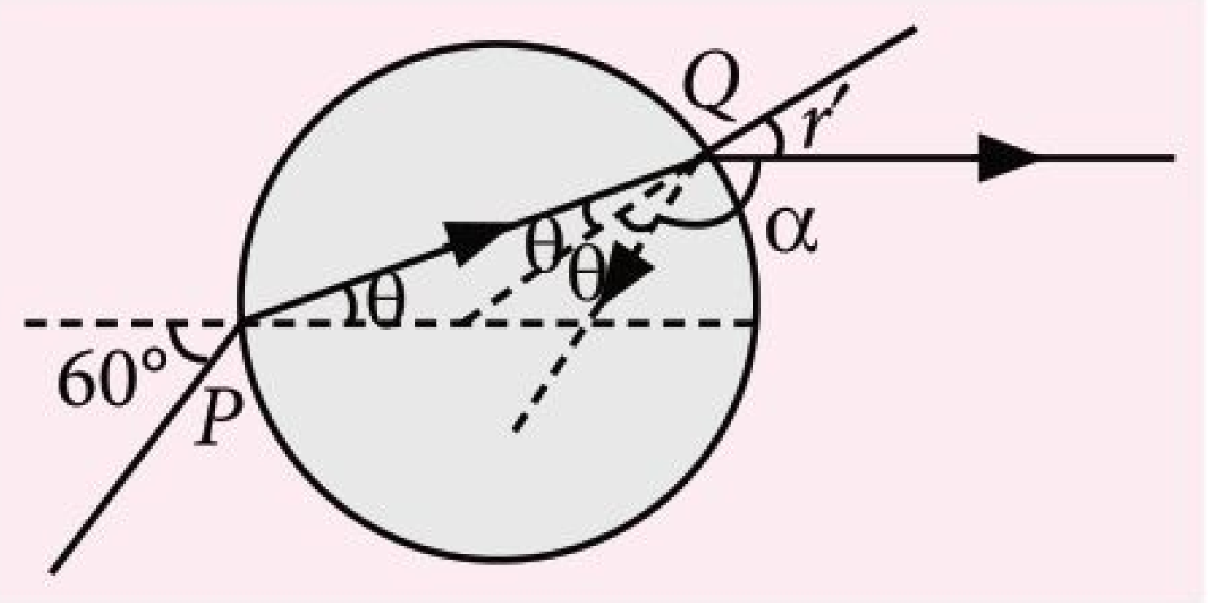
4. **(c) :** Magnetic field exerts a force $= Bev\sin\theta$
$= Bev\sin 0° = 0$

Electric field exerts force along a straight line.
The path of charged particle will be a straight line.

5. **(c) :** Using snell's law at point P, $\sin 60° = \mu\sin\theta$

$$\Rightarrow \frac{\sqrt{3}}{2} = \sqrt{3}\sin\theta$$

$$\theta = \sin^{-1}\left(\frac{1}{2}\right) = 30°$$



For the second surface,
$\mu\sin\theta = \sin r' \Rightarrow \sqrt{3}\sin 30° = \sin r'$

$$\sin r' = \frac{\sqrt{3}}{2} \Rightarrow r' = 60°$$

Required angle, $\alpha = 180° - (\theta + r') = 180° - (30° + 60°)$
Hence, $\alpha = 90°$

6. **(c) :** According to Kepler's law, $T^2 \propto r^3$

$$\therefore \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{4}\right)^3 = \frac{1}{64} \text{ or } \frac{T_1}{T_2} = \frac{1}{8}$$

or $T_2 = 8T_1 = 8 \times 5 = 40$ hour

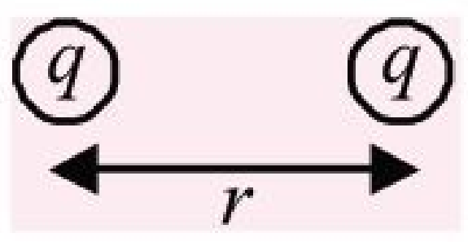
7. (a) : Initially force between spheres A and B,

$$F = \frac{kq^2}{r^2} \quad \text{...(i)}$$

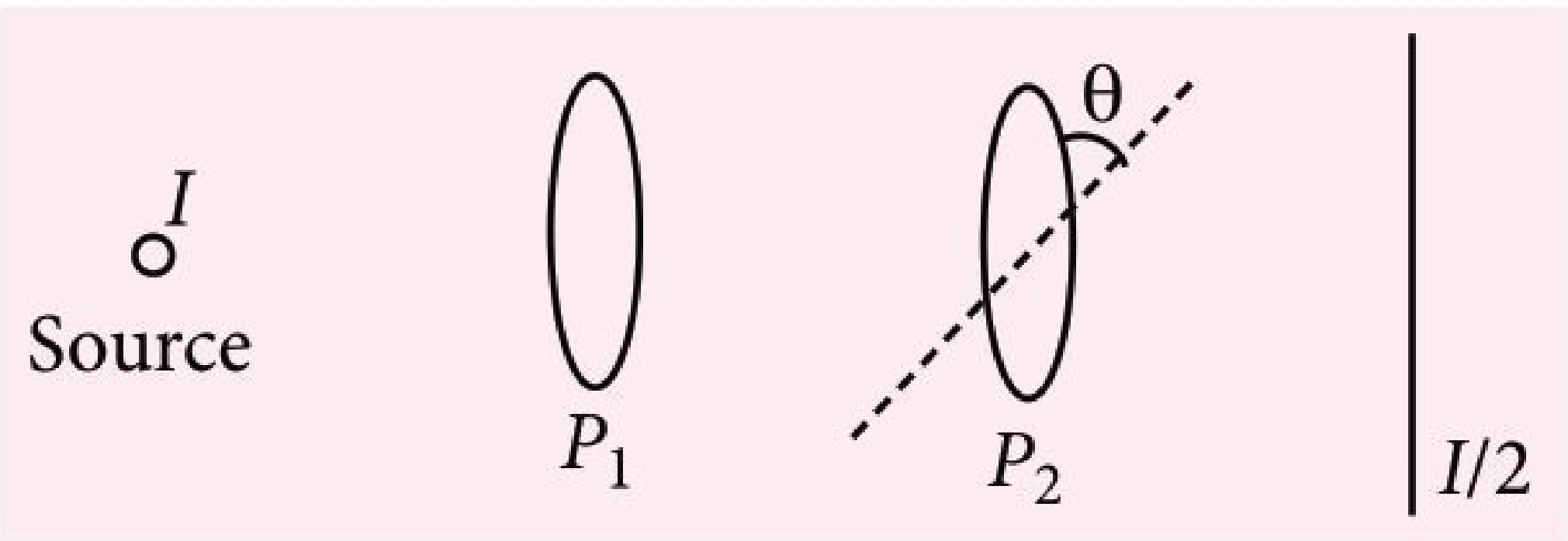
When A and C are touched, charge on both will be $\frac{q}{2}$. Again C is touched with B, the charge on both is given by $q_B = q_C = \frac{\frac{q}{2}+q}{2} = \frac{3q}{4}$

Required force between spheres A and B is given by

$$F' = \frac{kq_Aq_B}{r^2} = \frac{k \times \frac{q}{2} \times \frac{3q}{4}}{r^2} = \frac{3}{8}\frac{kq^2}{r^2} = \frac{3}{8}F$$



8. (a) : Let P_2 is rotated by angle θ.



By the law of Malus, $I = I_0 \cos^2\theta$

$$\frac{3I}{8} = \frac{I_0}{2}\cos^2\theta$$

$$\Rightarrow \cos^2\theta = \frac{3}{4} \Rightarrow \cos\theta = \frac{\sqrt{3}}{2} \Rightarrow \theta = 30°$$

9. (d) : Let N_0 is the initial activity.

N = undecayed part = $\frac{N_0}{8}$ (Given) ; Time = 30 years

By the formula of radioactivity, $N = N_0\left(\frac{1}{2}\right)^n$

where, n is number of half-lives.

$$\frac{N_0}{8} = N_0\left(\frac{1}{2}\right)^n ; \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$$

$n = \frac{t}{T_{1/2}}$ where $T_{1/2}$ is half-life.

$$\Rightarrow 3 = \frac{30}{T_{1/2}} \Rightarrow T_{1/2} = 10 \text{ years}$$

10. (a): Here, force (F), length (L) and time (T) are used as fundamental quantities.

$\therefore \quad d \propto F^a L^b T^c$

Also, $[d] = [ML^{-3}]$, $[F] = [MLT^{-2}]$

$\therefore$ Using principle of homogeneity of dimension

$[ML^{-3}T^0] = [MLT^{-2}]^a [M^0LT^0]^b [M^0L^0T]^c$

$ML^{-3}T^0 = M^aL^{a+b}T^{-2a+c}$

On comparing powers on both sides, we get

$a = 1$, $a + b = -3$ and $-2a + c = 0$

On solving these equations, we get

$a = 1$, $b = -4$ and $c = 2$

$\therefore \quad [d] = [FL^{-4}T^2]$

11. (c) : I is showing absorption photon.

From rest of three, III having maximum energy from $\Delta E \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

12. (a) : Energy radiated $E = \sigma T^4 \times (\text{area } 4\pi R^2) \times \text{time} \times e$

$$\frac{E_1}{E_2} = \frac{(4000)^4 \times (1)^2 \times 1 \times 4\pi\sigma e}{(2000)^4 \times (4)^2 \times 1 \times 4\pi\sigma e} = \frac{1}{1}$$

13. (c) : Momentum, $p = \sqrt{2mE}$ and $E = eV$

So, de-Broglie wavelength of the electron is given by, $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2\,meV}}$

$$= \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 50}}$$

$= 1.7 \times 10^{-10}$ m = 1.7 Å

14. (a) : Band gap = Energy of photon of λ = 2480 nm

$\therefore$ Energy $= \frac{hc}{\lambda}\text{ J} = \frac{hc}{\lambda e}\text{eV}$

$\therefore$ Band gap

$$= \frac{(6.63 \times 10^{-34}) \times (3 \times 10^8)}{(2480 \times 10^{-9}) \times (1.6 \times 10^{-19})}\text{eV} = 0.5\text{ eV}$$

15. (a)

16. (a) : Least count of the screw gauge

$$= \frac{0.5\text{ mm}}{50} = 0.01\text{ mm}$$

Main scale reading = 3 mm.

Vernier scale reading = 35

$\therefore$ Observed reading = 3 + 0.35 = 3.35

Zero error = –0.03

$\therefore$ Actual diameter of the wire = 3.35 – (–0.03) = 3.38 mm.

17. (d): Microwave – 10^{-3} m; Gamma rays – 10^{-15} m

A.M radiowaves – 100 m; X-rays – 10^{-10} m

18. (c)

19. (a) : Given : $x = x_0 \cos\left(\omega t - \frac{\pi}{4}\right)$ ...(i)

Acceleration $a = A\cos(\omega t + \delta)$ ...(ii)

Velocity $v = \frac{dx}{dt}$ or $v = -x_0\omega \sin\left(\omega t - \frac{\pi}{4}\right)$ ...(iii)

Acceleration $a=\frac{dv}{dt}=-x_0\omega^2\cos\left(\omega t-\frac{\pi}{4}\right)$

$$=x_0\omega^2\cos\left[\pi+(\omega t-\frac{\pi}{4})\right]=x_0\omega^2\cos\left[\omega t+\frac{3\pi}{4}\right] \quad \text{...(iv)}$$

Compare (iv) with (ii), we get $A=x_0\omega^2,\ \delta=\frac{3\pi}{4}$.

20. (d): Resistance of a wire of length l and radius r is given by

$$R=\frac{\rho l}{A}=\frac{\rho l}{A}\times\frac{A}{A}=\frac{\rho V}{A^2}=\frac{\rho V}{\pi^2 r^4} \qquad (\because\ V=Al)$$

i.e., $R\propto\frac{1}{r^4}\quad\therefore\ \frac{R_1}{R_2}=\left(\frac{r_2}{r_1}\right)^4$

Here, $R_1=100\ \Omega$, $r_1=r$, $r_2=r/2$, $R_2=?$

$$\therefore\quad R_2=R_1\left(\frac{r_1}{r_2}\right)^4=16R_1=1600\ \Omega$$

21. (580) : $x=10+8t-3t^2$, $y=5-8t^3$

$v_x=8-6t$, $v_y=-24t^2$; $\vec{v}_{x(t=1\,s)}=2\hat{i}$, $\vec{v}_{y(t=1\,s)}=-24\hat{j}$

So, the required speed

$$v_{\text{net}}=\sqrt{v_x^2+v_y^2}=\sqrt{4+576}=\sqrt{580}$$

$\therefore\quad v=580\ \text{m s}^{-1}$

22. (2500) : Given, energy dissipated,

$H=10\ \text{mJ}=10\times10^{-3}\ \text{J}=10^{-2}\ \text{J}$

Time, $t=1$ s

Electric current, $I=2\ \text{mA}=2\times10^{-3}$ A

Let R be the resistance of resistor,

From Joule's law, $H=I^2Rt$

$\Rightarrow\quad 10^{-2}=(2\times10^{-3})^2\times R\times1$

$$\therefore\quad R=\frac{1\times10^6}{100\times4}=2500\ \Omega$$

23. (5)

24. (198) : Here, $\lambda=6000\times10^{-10}$ m, $d=0.6\times10^{-4}$ m

For minima, $d\sin\theta=n\lambda$

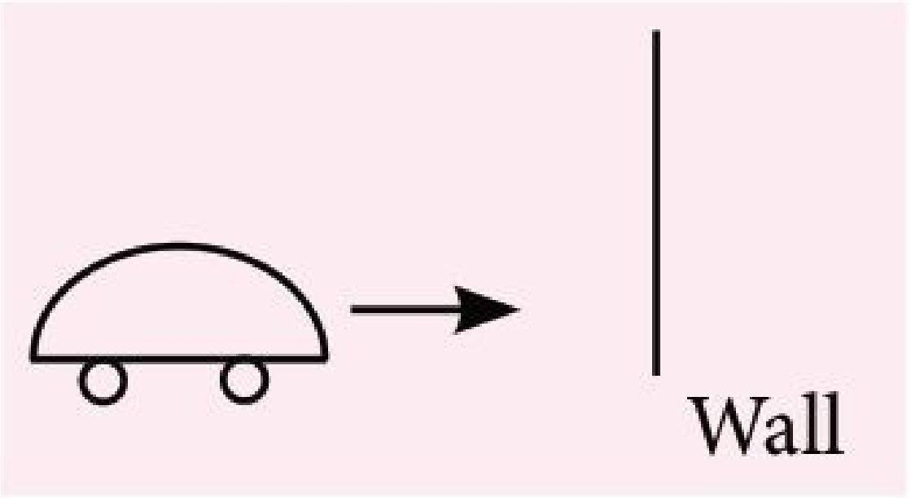
$$\sin\theta=\frac{n\lambda}{d}\le1,\ n\le\frac{d}{\lambda},\ n\le\frac{0.6\times10^{-4}}{6000\times10^{-10}}=100,$$

Since $n=100$ will corresponds to infinity so, maximum possible number of minima on one side is 99 and on both sides it is 198.

25. (132) : $v_s=330\ \text{m s}^{-1}$

$f=400$ Hz, $f=500$ Hz

Frequency received by wall,



$$f'=\left(\frac{v_s}{v_s-v}\right)f_0 \quad \text{...(i)}$$

f_0 = natural frequency; v = speed of car

Reflected frequency

$$f''=\left(\frac{v_s+v}{v_s}\right)f' \text{ ...(ii)},\quad f''=\frac{v_s+v}{v_s}\cdot\frac{v_s}{v_s-v}\cdot f_0$$

$$f''=\frac{v_s+v}{v_s-v}f_0;\ \frac{500}{400}=\frac{330+v}{330-v}$$

$v=36.7\ \text{m s}^{-1}=132\ \text{km h}^{-1}$

26. (5) : Main scale – 40 division → 1 cm

$50\ \text{VSD}=49\ \text{MSD};\ 1\ \text{VSD}=\frac{49}{50}\ \text{MSD}$

$\text{LC}=1\ \text{MSD}-1\ \text{VSD}=\left(1-\frac{49}{50}\right)\text{MSD}$

$\text{LC}=\frac{1}{50}\times\frac{1}{40}\ \text{cm}=5\times10^{-4}\ \text{cm}=5\times10^{-6}\ \text{m}$

27. (20)

28. (3) : Bulk modulus of the gas is given by $K=\frac{-P}{\left(\frac{\Delta V}{V_0}\right)}$

(Here negative sign indicates the decrease in volume with pressure)

or $\frac{\Delta V}{V_0}=\frac{P}{K}$ ...(i)

Also, $V=V_0(1+\gamma\Delta T)$ or $\frac{\Delta V}{V_0}=\gamma\Delta T$ ...(ii)

Comparing eq. (i) and (ii), we get

$$\frac{P}{K}=\gamma\Delta T\ \Rightarrow\ \Delta T=\frac{P}{K\gamma}\ \Rightarrow\ \Delta T=\frac{P}{3\alpha K}\quad(\because\ \gamma=3\alpha)$$

29. (250) **30. (33.3)**

◆◆

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CHAPTERWISE PRACTICE PAPER 2023

CUET (UG)

Exam on
21st to 31st
May 2023

SERIES - V Electromagnetic Waves

Section II of CUET (UG) is Domain specific. In this section of Physics, 40 questions to be attempted out of 50.

Time Allowed : 45 Minutes

Maximum Marks : 200

MULTIPLE CHOICE QUESTIONS (MCQs)

1. The electric field associated with an *EM* wave in vacuum is given by $\vec{E} = \hat{i}\,40\cos(kz - 6\times 10^{8}t)$, where *E*, *z* and *t* are in volt m^{-1}, meter and seconds respectively. The value of wave vector *k* is
(a) 2 m^{-1} (b) 0.5 m^{-1} (c) 6 m^{-1} (d) 3 m^{-1}

2. An electromagnetic wave of intensity *I* is incident on a non-reflecting surface. If *c* is the speed of light in free space, then the ratio $\frac{I}{c}$ is same as
(a) momentum (b) force
(c) pressure (d) pressure per unit area

3. The ratio of amplitude of magnetic field to the amplitude of electric field for an electromagnetic wave propagating in vacuum is equal to
(a) the speed of light in vacuum
(b) reciprocal of speed of light in vacuum
(c) the ratio of magnetic permeability to the electric susceptibility of vacuum
(d) unity

4. A capacitor of capacitance '*C*', is connected across an ac source of voltage *V*, is given by $V = V_0\sin\omega t$ The displacement current between the plates of the capacitor, would be given by
(a) $I_d = V_0\omega C\sin\omega t$ (b) $I_d = V_0\omega C\cos\omega t$
(c) $I_d = \frac{V_0}{\omega C}\cos\omega t$ (d) $I_d = \frac{V_0}{\omega C}\sin\omega t$

5. The correct order of arrangement of electromagnetic waves according to their wavelength is
(a) Gamma rays < Micro waves < AM radio waves < FM radio waves
(b) Micro waves < AM radio waves < FM radio wave < Gamma rays
(c) Gamma rays < AM radio waves < FM radio wave < Micro waves
(d) Gamma rays < Micro waves < FM radio waves < AM radio waves

6. Assume that a radio station is about 200 km away from your location and the station operates at 972 kHz. How long does it take for an electromagnetic signal to travel from the station to you and how many wave crests does it send out per second ?
(a) 666 μs and 9.72 × 10^{5} crests per second
(b) 666 μs and 972 × 10^{5} crests per second
(c) 555 μs and 97.2 × 10^{7} crests per second
(d) 555 μs and 0.972 × 10^{5} crests per second

7. Consider an electromagnetic wave propagating in vacuum. Choose the correct statement.
(a) For an electromagnetic wave propagating in + *y* direction, the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(x,t)\hat{z}$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(x,t)\hat{y}$.
(b) For an electromagnetic wave propagating in + *y* direction the electric fields is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(x,t)\hat{y}$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(x,t)\hat{z}$.
(c) For an electromagnetic wave propagating in + *x* direction, the electric field is $\vec{E} = \frac{1}{\sqrt{2}}E_{yz}(y,z,t)(\hat{y}+\hat{z})$ and the magnetic field is $\vec{B} = \frac{1}{\sqrt{2}}B_{yz}(y,z,t)(\hat{y}+\hat{z})$.

(d) For an electromagnetic wave propagating in $+x$ direction, the electric field is $\vec{E}=\frac{1}{\sqrt{2}}E_{yz}(x,t)(\hat{y}-\hat{z})$ and the magnetic field is $\vec{B}=\frac{1}{\sqrt{2}}B_{yz}(x,t)(\hat{y}+\hat{z})$.

8. The electric field of a certain plane e.m. wave is given by

$E_x = 0, E_y = 0, E_z = 2.0\cos\left[\pi\times10^{15}\left(t-\frac{x}{c}\right)\right].$

The wave is propagating in the positive x-direction. Find the expressions for the components of the magnetic field of the wave.

(a) $B_x=0, B_y=6.7\times10^{-9}\cos\left[\pi\times10^{16}\left(t-\frac{x}{c}\right)\right], B_z=0$

(b) $B_x=0, B_y=-6.7\times10^{-9}\cos\left[\pi\times10^{15}\left(t-\frac{x}{c}\right)\right], B_z=0$

(c) $B_x = 0, B_y = 0, B_z = 2.0\cos\left[\pi\times10^{15}\left(t-\frac{x}{c}\right)\right]$

(d) $B_x = 0, B_y = 0, B_z = -6.7\times10^{-9}\cos\left[\pi\left(t-\frac{x}{c}\right)\right]$

9. For plane electromagnetic waves propagating in the z direction, which one of the following combination gives the correct possible direction for $\vec{E}$ and $\vec{B}$ field respectively?

(a) $(\hat{i}+2\hat{j})$ and $(2\hat{i}-\hat{j})$ (b) $(-2\hat{i}-3\hat{j})$ and $(3\hat{i}-2\hat{j})$

(c) $(2\hat{i}+3\hat{j})$ and $(\hat{i}+2\hat{j})$ (d) $(3\hat{i}+4\hat{j})$ and $(4\hat{i}-3\hat{j})$

10. The condition under which a microwave oven heats up a food item containing water molecules most efficiently is

(a) Microwaves are heat waves, so always produce heating.

(b) Infra-red waves produce heating in a microwave oven.

(c) The frequency of the microwaves must match the resonant frequency of the water molecules.

(d) The frequency of the microwaves has no relation with natural frequency of water molecules

11. The ratio of the amplitude of the electric field to that of the magnetic field ($|E|/|H|$) of an electromagnetic wave travelling in vacuum is always

(a) equal to 1 (b) greater than 1

(c) less than 1 (d) zero

12. Which one of the following is the property of a monochromatic, plane electromagnetic wave in free space?

(a) Electric and magnetic fields have a phase difference of $\pi/2$.

(b) The energy contribution of both electric and magnetic fields are equal.

(c) The direction of propagation is in the direction of electric field E.

(d) The pressure exerted by the wave is the product of energy density and the speed of the wave.

13. A plane electromagnetic wave travels in free space along X-direction. If the value of $\vec{B}$ (in tesla) at a particular point in space and time is $1.2\times10^{-8}\hat{k}$. The value of $\vec{E}$ (in V m^{-1}) at that point is

(a) $1.2\hat{j}$ (b) $3.6\hat{k}$ (c) $1.2\hat{k}$ (d) $3.6\hat{j}$

14. A plane electromagnetic wave, has frequency of 2.0×10^{10} Hz and its energy density is 1.02×10^{-8} J m^{-3} in vacuum. The amplitude of the magnetic field of the wave is close to ($\frac{1}{4\pi\varepsilon_0}=9\times10^9$ N m^2 C^{-2} and speed of light = 3×10^8 m s^{-1})

(a) 150 nT (b) 160 nT (c) 180 nT (d) 190 nT

15. What does the Poynting vector represent?

(a) Power flowing across unit area in an electromagnetic field.

(b) Charge flowing across unit area per unit time in an electromagnetic field.

(c) Momentum flowing across unit area per unit time in an electromagnetic field.

(d) Angular momentum flowing across unit area per unit time in an electromagnetic field.

16. If v_g, v_x and v_m are the speeds of gamma-rays, X-rays and micro waves respectively in vacuum, then

(a) $v_g > v_x > v_m$ (b) $v_g < v_x < v_m$

(c) $v_g > v_x < v_m$ (d) $v_g = v_x = v_m$

17. Out of the following options which one can be used to produce a propagating electromagnetic wave?

(a) A charge moving at constant velocity

(b) A stationary charge

(c) A chargeless particle

(d) An accelerating charge

18. The energy of the em waves is of the order of 15 keV. To which part of the spectrum does it belong?
(a) Ultraviolet rays (b) γ-rays
(c) X-rays (d) Infra-red rays

19. If an electromagnetic wave of frequency 5 MHz travels from vacuum into a dielectric medium of electrical permittivity $\varepsilon_r = 4$, then its (take $\mu_r = 1$)
(a) wavelength is halved and the frequency remains unchanged
(b) wavelength and frequency are both doubled
(c) wavelength and frequency both remain unchanged
(d) wavelength is doubled but the frequency remains unchanged

20. The transverse nature of electromagnetic waves is proved by which of the following?
(a) Interference phenomena
(b) Diffraction phenomena
(c) Dispersion phenomena
(d) Polarization phenomena

21. In electromagnetic waves travelling in vacuum
1. The electric field $\vec{E}$ is always perpendicular to the magnetic field $\vec{B}$.
2. The cross product $\vec{E} \times \vec{B}$ always gives the direction in which the waves travel.
3. The fields $\vec{E}$ and $\vec{B}$ vary sinusoidally.
4. There is a phase difference of $\pi/2$ between $\vec{E}$ and $\vec{B}$.

The correct statement(s) is (are)
(a) 1, 3 (b) 1, 3, 4
(c) 1, 2, 3, 4 (d) 1, 2, 3

22. Arrange the following electromagnetic radiations per quantum in the order of increasing energy :
A : Blue light B : Yellow light
C : X-ray D : Radiowave
(a) D, B, A, C (b) A, B, D, C
(c) C, A, B, D (d) B, A, D, C

23. A galaxy is moving away from an observer on earth so that sodium light of wavelength 5892 Å is observed at 5896 Å. The speed of galaxy is
(a) 306 km s^{-1} (b) 204 km s^{-1}
(c) 185 km s^{-1} (d) 158 km s^{-1}

24. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi\upsilon\left(\frac{z}{c} - t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z - ct)]$ in medium, where the wave number k and frequency υ refer to their values in air. The medium is non-magnetic. If ε_{r_1} and ε_{r_2} refer to relative permittivities of air and medium respectively, which of the following options is correct?

(a) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 4$ (b) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = 2$ (c) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{4}$ (d) $\frac{\varepsilon_{r_1}}{\varepsilon_{r_2}} = \frac{1}{2}$

25. A plane electromagnetic wave propagating in the x-direction has wavelength of 6.0 mm. The electric field is in the y-direction and its maximum magnitude is 33 V m^{-1}. The equation for the electric field as a function of x and t is
(a) $11 \sin \pi(t - x/c)$
(b) $33 \sin \pi \times 10^{11}(t - x/c)$
(c) $33 \sin \pi(t - x/c)$
(d) $11 \sin \pi \times 10^{11}(t - x/c)$

26. If the surface is a perfect reflector, the change in momentum of the wave after falling on the surface is
(a) P (b) $2P$ (c) $\frac{1}{2}P$ (d) $-2P$

27. If the magnetic field of a plane electromagnetic wave is given by

$$B = 100 \times 10^{-6} \sin\left[2\pi \times 2 \times 10^{15}\left(t - \frac{x}{c}\right)\right]$$

then the maximum electric field associated with it is (The speed of light = 3×10^8 m s^{-1})
(a) 4.5×10^4 N C^{-1} (b) 4×10^4 N C^{-1}
(c) 6×10^4 N C^{-1} (d) 3×10^4 N C^{-1}

28. A monochromatic beam of light has a frequency $\upsilon = \frac{3}{2\pi} \times 10^{12}$ Hz and is propagating along the direction $\frac{\hat{i} + \hat{j}}{\sqrt{2}}$. It is polarized along the $\hat{k}$ direction. The acceptable form for the magnetic field is

(a) $\frac{E_0}{c}\frac{(\hat{i} + \hat{j} + \hat{k})}{\sqrt{3}}\cos\left[10^4\frac{(\hat{i} + \hat{j})}{\sqrt{2}} \cdot \vec{r} + (3 \times 10^{12})t\right]$

(b) $\frac{E_0}{c}\frac{(\hat{i} - \hat{j})}{\sqrt{2}}\cos\left[10^4\frac{(\hat{i} + \hat{j})}{\sqrt{2}} \cdot \vec{r} - (3 \times 10^{12})t\right]$

(c) $\frac{E_0}{c}\frac{(\hat{i}-\hat{j})}{\sqrt{2}}\cos\left[10^4\frac{(\hat{i}-\hat{j})}{\sqrt{2}}\cdot\vec{r}-(3\times10^{12})t\right]$

(d) $\frac{E_0}{c}\hat{k}\cos\left[10^4\frac{(\hat{i}+\hat{j})}{\sqrt{2}}\cdot\vec{r}+(3\times10^{12})t\right]$

29. Light with an energy flux of 25×10^4 W m^{-2} falls on a perfectly reflecting surface at normal incidence. If the surface area is 15 cm^2, the average force exerted on the surface is

(a) 1.25×10^{-6} N (b) 2.50×10^{-6} N
(c) 1.20×10^{-6} N (d) 3.0×10^{-6} N

30. The electric field component of a monochromatic radiation is given by $\vec{E} = 2E_0\hat{i}\cos kz\ \cos\omega t$.

Its magnetic field $\vec{B}$ is then given by

(a) $\frac{2E_0}{c}\hat{j}\cos kz\cos\omega t$ (b) $\frac{2E_0}{c}\hat{j}\sin kz\cos\omega t$

(c) $\frac{2E_0}{c}\hat{j}\sin kz\sin\omega t$ (d) $-\frac{2E_0}{c}\hat{j}\sin kz\sin\omega t$

31. The electric field portion of an electromagnetic wave is given by (all variables in SI units)

$E = 10^{-4}\sin(6 \times 10^5\, t - 0.01\, x)$. The frequency ($f$) and the speed ($v$) of electromagnetic wave are

(a) $f = 30/\pi$ kHz and $v = 1.5 \times 10^7$ m s^{-1}
(b) $f = 90/\pi$ kHz and $v = 6.0 \times 10^7$ m s^{-1}
(c) $f = 300/\pi$ kHz and $v = 6.0 \times 10^7$ m s^{-1}
(d) $f = 600/\pi$ kHz and $v = 7.5 \times 10^7$ m s^{-1}

32. The electric field of a plane electromagnetic wave of amplitude 2 V m^{-1} varies with time and propagates along z-axis. The average energy density of the magnetic field (in J m^{-3}) is

(a) 13.29×10^{-12} (b) 8.86×10^{-12}
(c) 17.72×10^{-12} (d) 4.43×10^{-12}

33. γ-rays are detected by

(a) point contact diodes (b) thermopiles
(c) ionization chamber (d) photocells

34. In an electromagnetic wave in free space the root mean square value of the electric field is $E_{rms} = 6$ V m^{-1}. The peak value of the magnetic field is

(a) 2.83×10^{-8} T (b) 0.70×10^{-8} T
(c) 4.23×10^{-8} T (d) 1.41×10^{-8} T

ASSERTION & REASONING BASED MCQS

For question numbers 35-38, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Both assertion and reason are true and reason is the correct explanation of assertion.
(b) Both assertion and reason are true but reason is not the correct explanation of assertion.
(c) Assertion is true but reason is false.
(d) Both assertion and reason are false.

35. **Assertion :** UV radiation causes photo dissociation of ozone into O_2 and O, thus causing damage to the stratospheric ozone layer.
Reason : Ozone hole is resulting in global warming and climate change.

36. **Assertion :** Static crashes are heard on radio, when lightning flash occurs in the sky.

Reason : Electromagnetic waves having frequency of radio wave range interfere with radio waves.

37. **Assertion :** Electromagnetic radiations exert pressure.
Reason : Electromagnetic waves carry both momentum and energy.

38. **Assertion :** Microwaves have more energy than the radio waves.
Reason : Energy of wave is directly proportional to the frequency.

MATCH THE FOLLOWING

39. Various electromagnetic waves are given in column I and various frequency ranges in column II.

Column I		Column II	
(A)	Radiowaves	(P)	1×10^{16} to 3×10^{21} Hz
(B)	γ-rays	(Q)	1×10^9 to 3×10^{11} Hz
(C)	Microwaves	(R)	3×10^{18} to 5×10^{22} Hz
(D)	X-rays	(S)	5×10^5 to 10^9 Hz

(a) (A) → (P); (B) → (Q); (C) → (R); (D) → (S)
(b) (A) → (Q); (B) → (R); (C) → (S); (D) → (P)
(c) (A) → (R); (B) → (S); (C) → (P); (D) → (Q)
(d) (A) → (S); (B) → (R); (C) → (Q); (D) → (P)

40. Match the entries in column I with the column II and select the correct options.

Column I		Column II	
(A)	$\oint\vec{B}\cdot d\vec{l} = \mu_0 I$	(P)	Gauss's law in electrostatics
(B)	$\oint\vec{B}\cdot d\vec{l} = \mu_0\left(I+\epsilon_0\frac{d\phi_E}{dt}\right)$	(Q)	Faraday's laws of electromagnetic induction

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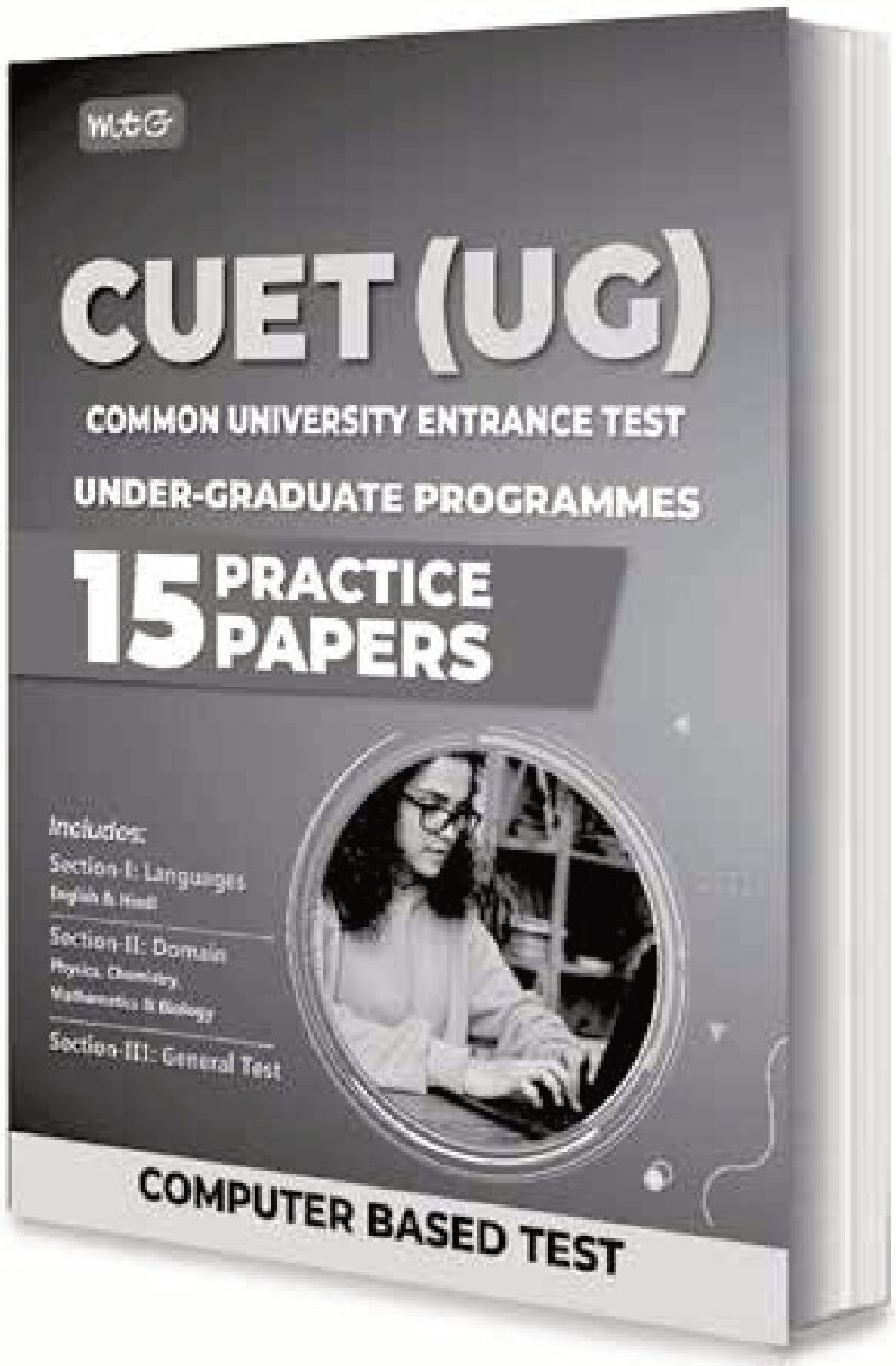
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(C)	$\oint \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\cdot d\vec{l}$ $\oint_S \vec{B}$	(R)	Ampere Maxwell's law
(D)	$\oint \vec{E}\cdot d\vec{s} = \frac{q}{\epsilon_0}$	(S)	Ampere's circuital law

(a) (A) → (S); (B) → (P); (C) → (Q); (D) → (R)
(b) (A) → (S); (B) → (Q); (C) → (R); (D) → (P)
(c) (A) → (S); (B) → (R); (C) → (Q); (D) → (P)
(d) (A) → (S); (B) → (S); (C) → (P); (D) → (Q)

CASE BASED MCQs

Case I : Read the passage given below and answer the following questions from 41 to 45.

In a plane electromagnetic wave, the electric field varies with time having an amplitude 1 V m^{-1}. The frequency of wave is 0.5×10^{15} Hz. The wave is propagating along Z-axis.

41. What is the average energy density of electric field
(a) 1.2×10^{-12} J m^{-3} (b) 3.2×10^{-10} J m^{-3}
(c) 2.2×10^{-12} J m^{-3} (d) 2.8×10^{-10} J m^{-3}

42. What is the average energy density of magnetic field?
(a) 1.5×10^{-10} J m^{-3} (b) 2.6×10^{-14} J m^{-3}
(c) 1.1×10^{-12} J m^{-3} (d) 2.2×10^{-12} J m^{-3}

43. What is the average energy density of total field?
(a) 3.2×10^{-10} J m^{-3} (b) 1.6×10^{-12} J m^{-3}
(c) 2.2×10^{-12} J m^{-3} (d) 4.42×10^{-12} J m^{-3}

44. What is the amplitude of magnetic field?
(a) 3.33×10^{-9} T (b) 4.42×10^{-12} T
(c) 1.51×10^{-10} T (d) 1.0×10^{-12} T

45. The equation for magnetic field as a function of x and t is
(a) $3.3 \times 10^{-9} \sin \pi \times 10^{15} (t - x/c)$
(b) $1.3 \times 10^{-7} \sin \pi \times 10^{15} (t - x/c)$
(c) $3.0 \times 10^{8} \sin \pi \times 10^{14} (t - x/c)$
(d) none of these

Case II : Read the passage given below and answer the following questions from 46 to 50.

When a capacitor of capacitance C after charging with a charge Q is connected to inductor of self inductance L, the oscillations of charge takes place with time between the two plates of capacitor. If one plate of capacitor is connected to antenna and other plate is earthed, then electromagnetic waves are produced, which are sinusoidal variation of electric and magnetic field vectors, perpendicular to each other as well as perpendicular to the direction of propagation of wave. The velocity of these waves depends upon the electric and magnetic properties of the medium.

The electromagnetic waves were produced experimentally by Hertz in 1888 using Hertz Oscillator, which were of wavelength 6 m. Jagdish chandra Bose in 1895 produced these waves which were of wavelength 5 mm to 25 mm and in 1896, G. Marconi established a wireless communication between two stations 50 km apart using electromagnetic waves.

In an electromagnetic wave, the amplitude of electric field is 48 V m^{-1}. The frequency of wave is 2.0×10^{10} Hz. The wave is propagating along z-axis.

46. If μ_0, μ_r, ϵ_0 and ϵ_r as the absolute permeability, relative permeability, absolute permittivity and relative permittivity of the medium, then the velocity of electromagnetic wave in a medium is
(a) $\frac{1}{\sqrt{\mu_0 \epsilon_0}}$ (b) $\frac{1}{\sqrt{\mu_r \epsilon_r}}$
(c) $\frac{1}{\sqrt{\mu_0 \epsilon_0 \mu_r \epsilon_r}}$ (d) $\sqrt{\frac{\mu_r \epsilon_r}{\mu_0 \epsilon_0}}$

47. In electromagnetic wave, the average energy density due to magnetic field is
(a) 8.58×10^{-10} J m^{-3} (b) 4.42×10^{-10} J m^{-3}
(c) 5.1×10^{-9} J m^{-3} (d) 6.63×10^{-10} J m^{-3}

48. Calculate the wavelength of the wave.
(a) 3.0×10^{-2} m (b) 1.5×10^{-2} m
(c) 2.2×10^{-10} m (d) 2.5×10^{-2} m

49. Calculate the amplitude of oscillating magnetic field.
(a) 1.6×10^{-7} T (b) 1.2×10^{-5} T
(c) 1.5×10^{-6} T (d) 2.2×10^{-10} T

50. Sun also sends electromagnetic waves to earth. Which one of the electromagnetic waves out of the visible portion, from sun will be reaching the surface of earth earlier than the others ?
(a) violet waves (b) green waves
(c) yellow waves (d) red waves

SOLUTIONS

1. (a) : Compare the given equation with

$E = E_0\cos(kz - \omega t)$,

we get, $\omega = 6 \times 10^8\ \text{s}^{-1}$

$$\text{Wave vector, } k = \frac{\omega}{c} = \frac{6\times10^8\ \text{s}^{-1}}{3\times10^8\ \text{m s}^{-1}} = 2\ \text{m}^{-1}$$

2. (c) : The pressure exerted by an electromagnetic wave of intensity I on a non-reflecting surface is $P = \frac{I}{c}$

Thus, the ratio $\frac{I}{c}$ is same as pressure.

3. (b) : The amplitude of magnetic field and electric field for an electromagnetic wave propagating in vacuum are related as $E_0 = B_0 c$

where c is the speed of light in vacuum.

$$\therefore\ \frac{B_0}{E_0} = \frac{1}{c}$$

4. (b) : The instantaneous voltage, $V = V_0\sin\omega t$

$$\text{Displacement current is given by, } I_d = \frac{CdV}{dt}$$

$$I_d = \frac{Cd\,(V_0\sin\omega t)}{dt}$$

$I_d = CV_0\omega\cos\omega t$

5. (d) : According to their wavelength, the correct order of given electromagnetic waves is

Gamma rays < Micro waves < FM radio waves < AM radio waves.

6. (a) : Time taken by wave to travel

$$= \frac{200\ \text{km}}{3\times10^5\ \text{km s}^{-1}} = 6.667\times10^{-4}\ \text{s} \approx 666\ \mu\text{s}$$

Number of crests per second = Frequency

Frequency = 972 kHz = 9.72×10^5 Hz

$\therefore$ There are 9.72×10^5 crests per second.

7. (d) : An electromagnetic wave propagating in + x direction means electric field and magnetic field should be function of x and t.

Also, $\vec{E} \perp \vec{B}$ or $\hat{E} \perp \hat{B}$ *i.e.* $(\hat{y} - \hat{z})\cdot(\hat{y} + \hat{z}) = \hat{y}\cdot\hat{y} - \hat{z}\cdot\hat{z} = 0$

8. (b)

9. (b) : For electromagnetic wave, $\vec{E}$ and $\vec{B}$ are transverse in nature.

According to question,

$\vec{E}\times\vec{B} =$ direction of propagation = $+z$ direction.

Only option (b) satisfies both conditions (i) $\vec{E}\cdot\vec{B} = 0$ (ii) $(\vec{E}\times\vec{B})$ directed along the z-axis.

10. (c) : In microwave oven, the frequency of the microwaves must match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules.

11. (b) : The amplitudes of electric and magnetic fields of an electromagnetic wave travelling in vacuum are related as $|E| = c|H|$

$$\frac{|E|}{|H|} = c = 3\times10^8\ \text{m s}^{-1}$$

Thus $\frac{|E|}{|H|}$ is always greater than 1.

12. (b) : The electric and magnetic fields are in the same phase. The energy is equally divided between electric and magnetic fields.

The direction of propagation is perpendicular to both electric and magnetic fields.

The pressure exerted by the wave is equal to the energy density of the wave.

13. (d) : Here, $\vec{B} = 1.2\times10^{-8}\,\hat{k}$ T

The magnitude of $\vec{E}$ is

$E = Bc = (1.2 \times 10^{-8}\ \text{T})(3 \times 10^8\ \text{m s}^{-1}) = 3.6\ \text{V m}^{-1}$

$\vec{B}$ is along Z-direction and the wave propagates along X-direction. Therefore $\vec{E}$ should be in a direction perpendicular to both X and Z axes. Using vector algebra $\vec{E}\times\vec{B}$ should be along X-direction.

Since $(+\hat{j})\times(+\hat{k}) = \hat{i}$, $\vec{E}$ is along the Y-direction.

Thus, $\vec{E} = 3.6\hat{j}\ \text{V m}^{-1}$

TRIO

The same THREE LETTERS will complete these three words.

Can you find the three-letter sequence?

RE — — — TANCE

HYSTERE — — —

TRAN — — — TOR

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month.
Winners' names will be published in next issue.

14. (b): $f = 2 \times 10^{10}$ Hz ;
Energy density = 1.02×10^{-8} J m^{-3}

$$\frac{1}{2}\varepsilon_0 E^2 = 1.02 \times 10^{-8} \text{ or } E^2 = \frac{1.02 \times 2 \times 10^{-8}}{\varepsilon_0} \text{ or } E = 48 \text{ V}$$

$$B = \frac{E}{c} = \frac{48}{3 \times 10^8} = 16 \times 10^{-8} \Rightarrow B = 160 \text{ nT}$$

15. (a): Poynting vector represents power flowing across unit area in an electromagnetic field. The SI unit of poynting vector is W m^{-2}.

16. (d): In vacuum electromagnetic waves travel with the same speed *i.e.*, with the speed of light c (= 3×10^8 m s^{-1}).

$\therefore \quad v_g = v_x = v_m$

17. (d): Accelerating charge produces electromagnetic wave.

18. (c): As $\lambda = \dfrac{hc}{E}$

where the symbols have their usual meanings.
Here, E = 15 keV = 15×10^3 V and hc = 1240 eV nm

$$\therefore \quad \lambda = \frac{1240 \text{ eV nm}}{15 \times 10^3 \text{ eV}} = 0.083 \text{ nm}$$

As the wavelength range of X-rays is from 1 nm to 10^{-3} nm, so this wavelength belongs to X-rays.

19. (a)

20. (d): The phenomenon of polarization explains that the electromagnetic waves are transverse in nature.

21. (d)

22. (a): $E_{\text{radiowave}} < E_{\text{yellow}} < E_{\text{blue}} < E_{X\text{-ray}}$

23. (b): Here, $\Delta\lambda$ = 5896 Å – 5892 Å = 4 Å ; λ = 5892 Å

$$\text{As } \frac{\Delta\lambda}{\lambda} = \frac{v}{c} \quad \therefore \quad v = \frac{\Delta\lambda}{\lambda}c = \frac{4}{5892} \times 3 \times 10^8 \text{ m s}^{-1}$$

= 2.04×10^5 m s^{-1} = 204 km s^{-1}
Hence, the speed of galaxy is 204 km s^{-1}.

24. (c)

25. (b): $\omega = 2\pi\upsilon = \dfrac{2\pi c}{\lambda} = \dfrac{2\pi \times 3 \times 10^8}{6 \times 10^{-3}} = \pi \times 10^{11}$ rad s^{-1}

The equation for the electric field, along y-axis in the electromagnetic wave is given by

$$E_y = E_0 \sin\omega\left(t - \frac{x}{c}\right) = 33 \sin \pi \times 10^{11} (t - x/c)$$

26. (d): Let momentum of incident wave = P
Momentum of reflected wave = $-P$
(Since surface is a perfect reflector.)
Change in momentum of the wave = $-P - P = -2P$

27. (d): The maximum electric field, $E_0 = B_0 c$
= $100 \times 10^{-6} \times 3 \times 10^8 = 3 \times 10^4$ N C^{-1}

28. (b): $\vec{E} \times \vec{B}$ gives direction of wave propagation.

$$\Rightarrow \quad \hat{k} \times \vec{B} \,||\, \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

$$\text{Now, } \hat{k} \times \left(\frac{\hat{i} - \hat{j}}{\sqrt{2}}\right) = \frac{\hat{j} - (-\hat{i})}{\sqrt{2}} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

Wave propagation vector should be along $\dfrac{\hat{i} + \hat{j}}{\sqrt{2}}$ and direction of magnetic field is along $\dfrac{\hat{i} - \hat{j}}{\sqrt{2}}$.

29. (b): Here,
Energy flux, $I = 25 \times 10^4$ W m^{-2}
Area, A = 15 cm^2 = 15×10^{-4} m^2
Speed of light, $c = 3 \times 10^8$ m s^{-1}
For a perfectly reflecting surface, the average force exerted on the surface is

$$F = \frac{2IA}{c} = \frac{2 \times 25 \times 10^4 \text{ W m}^{-2} \times 15 \times 10^{-4} \text{ m}^2}{3 \times 10^8 \text{ m s}^{-1}}$$

= 250×10^{-8} N = 2.50×10^{-6} N

30. (c): $\dfrac{dE}{dz} = -\dfrac{dB}{dt}$

$$\frac{dE}{dz} = -2E_0 k \sin kz \cos\omega t = -\frac{dB}{dt}$$

$$dB = +\,2\,E_0 k \sin kz \cos\omega t\,dt$$

$$B = +2E_0 k \sin kz \int \cos\omega t\,dt = +2E_0 \frac{k}{\omega} \sin kz \sin\omega t$$

$$\frac{E_0}{B_0} = \frac{\omega}{k} = c$$

$$B = \frac{2E_0}{c} \sin kz \sin\omega t \qquad \therefore \quad \vec{B} = \frac{2E_0}{c} \sin kz \sin\omega t\,\hat{j}$$

31. (c): $E = 10^{-4} \sin(6 \times 10^5 t - 0.01\,x)$
$\omega = 6 \times 10^5$ rad s^{-1} ; $2\pi f = 6 \times 10^5$ rad s^{-1}

$$f = \frac{300}{\pi} \text{ kHz} \;;\; v = \frac{\omega}{k} = \frac{6 \times 10^5}{0.01} = 6 \times 10^7 \text{ m s}^{-1}$$

32. (b): Average energy density of the magnetic field is

$$u_B = \frac{1}{4}\frac{B_0^2}{\mu_0} = \frac{1}{4}\frac{E_0^{\,2}}{\mu_0 c^2} \quad \left(\because \quad B_0 = \frac{E_0}{c}\right)$$

$$\text{or } u_B = \frac{1}{4}\varepsilon_0 E_0^{\,2} \quad \left(\because \quad c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}\right)$$

$$= \frac{1}{4} \times 8.854 \times 10^{-12} \times (2)^2$$

= 8.854×10^{-12} J m^{-3} ≈ 8.86×10^{-12} J m^{-3}

33. (c) : γ-rays are detected by ionization chamber.

34. (a) : Given: $E_{\text{rms}} = 6\ \text{V m}^{-1}$

$$\frac{E_{\text{rms}}}{B_{\text{rms}}} = c \quad \text{or} \quad B_{\text{rms}} = \frac{E_{\text{rms}}}{c}$$

$$B_{\text{rms}} = \frac{6}{3\times10^8} = 2 \times 10^{-8}\ \text{T}$$

Since, $B_{\text{rms}} = \dfrac{B_0}{\sqrt{2}}$

where B_0 is the peak value of magnetic field.

$$\therefore \quad B_0 = B_{\text{rms}}\sqrt{2} = 2\times10^{-8}\times\sqrt{2}\ \text{T}$$

$B_0 \approx 2.83 \times 10^{-8}$ T

35. (b): $O_3 \xrightarrow{\text{UV (sun)}} O_2 + O$

36. (a)

37. (b): Electromagnetic waves transport energy, momentum and information. Electromagnetic waves exert radiation pressure on surface.

38. (a): Both the assertion and reason are true and reason is the correct explanation of assertion.
The frequency of microwave is much larger than the frequency of radio waves. Therefore equation $E = h\upsilon$ (where E = energy, h is Planck constant and υ is frequency) shows that the energy of micro-waves is much larger than the energy of radio waves.

39. (d): The frequency ranges of various waves are as under :
Radiowaves ; 5×10^5 to 10^9 Hz
γ-rays ; 3×10^{18} to 5×10^{22} Hz
Microwaves ; 1×10^9 to 3×10^{11} Hz
X-rays ; 1×10^{16} to 3×10^{21} Hz

40. (c)

41. (c) : Average energy density of electric field,

$$u_E = \frac{1}{2}\epsilon_0 E_{rms}^2 = \frac{1}{2}\epsilon_0\left(\frac{E_0}{\sqrt{2}}\right)^2 \left(\because E_{rms} = \frac{E_0}{\sqrt{2}}\right)$$

$$= \frac{1}{4}\epsilon_0 E_0^2 = \frac{1}{4}\times\left(8.854\times10^{-12}\right)\times1^2 = 2.21 \times 10^{-12}\ \text{J m}^{-3}$$

42. (d): Average energy density of magnetic field,
u_B = average energy density of electric field
$= 2.21 \times 10^{-12}$ J m^{-3}

43. (d): Total average energy density,
$u = u_E + u_B = 2\,u_E = 2 \times 2.21 \times 10^{-12} = 4.42 \times 10^{-12}$ J m^{-3}

44. (a) : Amplitude of magnetic field,
$B_0 = E_0/c = 1/(3 \times 10^8) = 3.33 \times 10^{-9}$ T

45. (a) : $B = B_Z = B_0 \sin\omega\left(t - \dfrac{x}{c}\right)$

$$= 3.3 \times 10^{-9} \sin 2\pi \times 0.5 \times 10^{15}\left(t - \frac{x}{c}\right)$$

$$= 3.3 \times 10^{-9} \sin \pi \times 10^{15}\left(t - \frac{x}{c}\right)$$

46. (c) : Velocity of E.M. wave,

$$v = \frac{1}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu_0\epsilon_0\mu_r\epsilon_r}}$$

47. (c) : Average energy density due to magnetic field in E.M. wave is

$$u_B = \frac{1}{2}\frac{B_{rms}^2}{\mu_0} = \frac{1}{2\mu_0}\left(\frac{B_0}{\sqrt{2}}\right)^2 = \frac{1}{4}\frac{B_0^2}{\mu_0}$$

$$= \frac{1}{4}\frac{(E_0/c)^2}{\mu_0} = \frac{E_0^2}{4\mu_0 c^2} = \frac{1}{4\mu_0}\left(\frac{E_0^2}{1/\mu_0\epsilon_0}\right) = \frac{1}{4}\epsilon_0 E_0^2$$

$$= \frac{1}{4}\times\left(8.85\times10^{-12}\right)\times(48)^2 = 5.1\times10^{-9}\ \text{J m}^{-3}$$

48. (b): $x = \dfrac{c}{\upsilon} = \dfrac{3\times10^8}{2.0\times10^{10}} = 1.5 \times 10^{-2}$ m

49. (a): $B_0 = \dfrac{E_0}{c} = \dfrac{48}{3\times10^8} = 1.6\times10^{-7}$ T

50. (d): $\mu = \dfrac{c}{v}$ or $v = \dfrac{c}{\mu}$ and $\mu = A + \dfrac{B}{\lambda^2} + \dfrac{C}{\lambda^4}$

As $\lambda_r > \lambda_v$ so $\mu_r < \mu_v$; therefore $v_r > v_v$

◆◆

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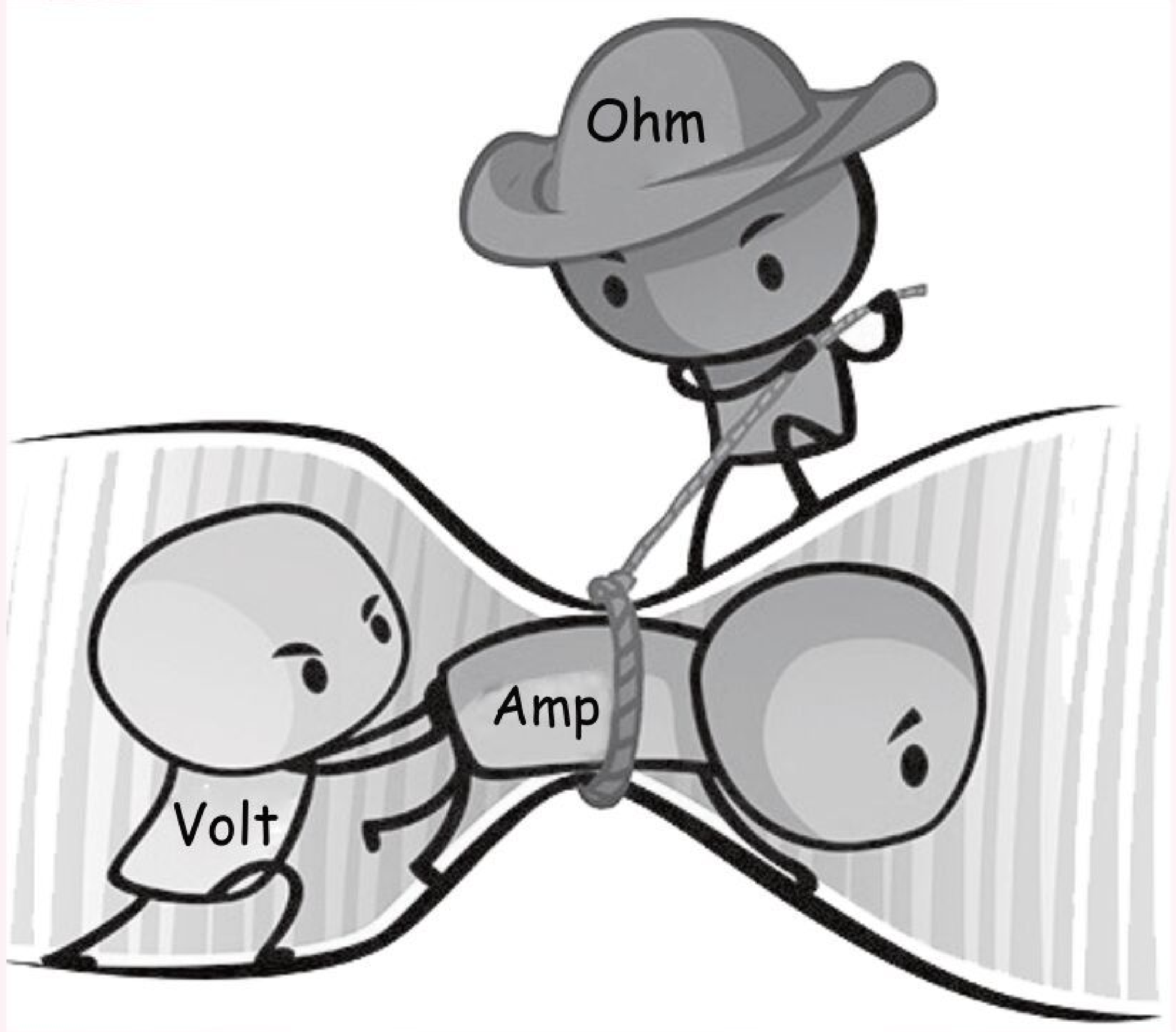

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IMUCET is mandatory for all B.Sc. in Nautical Science aspirants. Based on their **IMUCET rank** and **PCM aggregate percentage**, candidates are shortlisted. IMUCET (Indian Maritime University Common Entrance Examination) is an examination that takes place throughout the nation, conducted by the Indian Maritime University. However, some institutes organise their own entrance test also.

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2. IMU Kolkata
3. Indian Maritime University, Kochi Campus
4. Coimbatore Marine College, Coimbatore.
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6. Tolani Maritime Institute, Induri.

COLLEGE INFO : T.S. CHANAKYA INSTITUTE

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SELECTION CRITERIA

Aspirants wanted to pursue the course need to appear in Indian Maritime University Common Entrance Test **(IMUCET or JEE) and secure a good rank for an opportunity to study in T.S. Chanakya. IMUCET has 200 MCQ-type questions** of 10+2 level from Physics, Mathematics, Chemistry, English, General Knowledge, and Aptitude, in a duration of 180 minutes (3 hours). Shortlisted candidates (based on IMUCET rank) are asked for their relevant documents to appear for the admission process. After that, DG Shipping appointed doctors will conduct an eye-test and medical examination which confirms to the requirements of medical examination rules of the Directorate General of Shipping.

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CLASS XI

SYLLABUS*

Section – 1 : *Physics* : Units and Measurements, Mechanics, Properties of Matter, Heat and Thermodynamics, Oscillations, Waves.

Chemistry : Some Basic Concepts of Chemistry, Structure of Atom, Classification of Elements and Periodicity in Properties, Chemical Bonding and Molecular Structure, States of Matter, Thermodynamics, Equilibrium, Redox Reactions, Hydrogen, The *s*-Block Elements, The *p*-Block Elements (Groups 13 and 14), Organic Chemistry - Some Basic Principles and Techniques, Hydrocarbons, Environmental Chemistry.

Section – 2 : Higher Order Thinking Questions - Syllabus as per Section – 1.

Total Questions : 50

Time : 1 hr.

PATTERN & MARKING SCHEME			
Section	**(1) Physics & Chemistry**	**(2) Achievers Section**	**(3) Mathematics or Biology**
No. of Questions	25	5	20
Marks per Ques.	1	3	1

Section – 3 : Sets, Relations and Functions, Principle of Mathematical Induction, Logarithms, Complex Numbers & Quadratic Equations, Linear Inequations, Sequences and Series, Trigonometry, Straight Lines, Conic Sections, Permutations and Combinations, Binomial Theorem, Statistics, Mathematical Reasoning, Limits and Derivatives, Probability, Introduction to 3-D Geometry.

OR

Section – 3 : Diversity in the Living World, Structural Organisation in Plants and Animals, Cell : Structure and Functions, Plant Physiology, Human Physiology.

Practice Questions

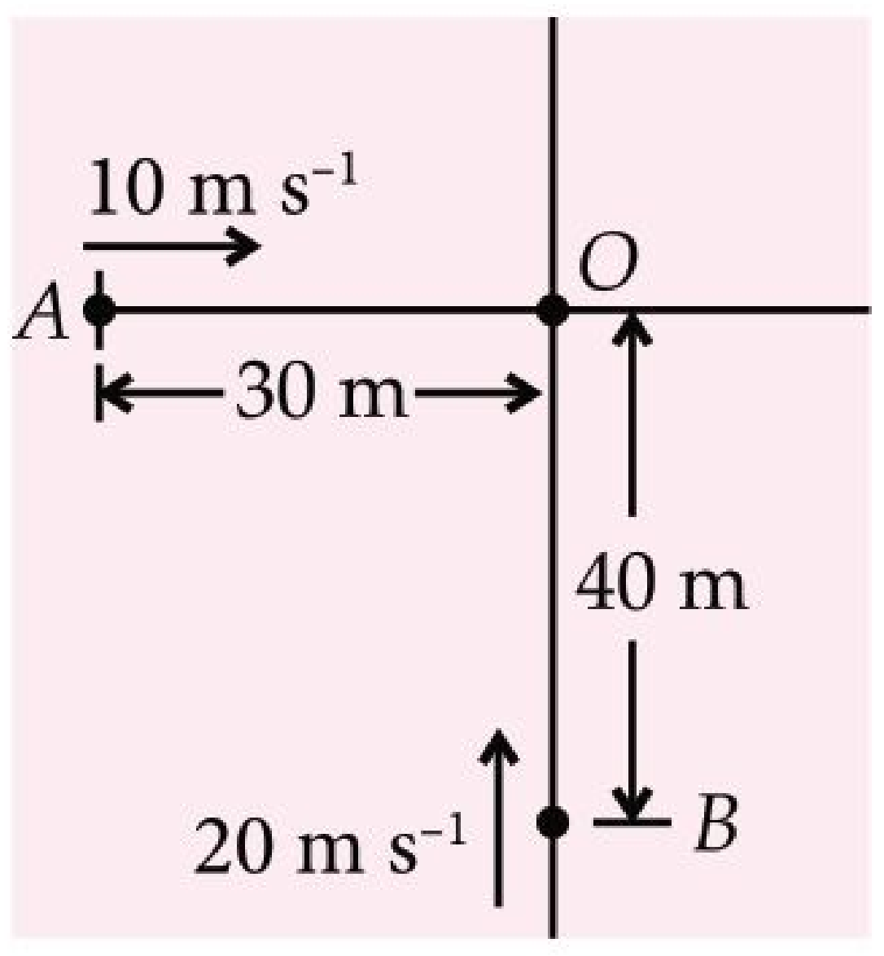
1. The velocity of transverse wave in a string is $v=\sqrt{T/m}$ where T is the tension in the string and m is the mass per unit length. If T = 3.0 kg – wt, the mass of string is 2.5 g and the length of string is l = 1.000 m, then the percentage error in the measurement of velocity is

A. 0.5% B. 0.7% C. 2.3% D. 3.6%

2. A car starts moving with acceleration $a = 5\text{ m s}^{-2}$, then moves uniformly for some time and then decelerates at $a = -5\text{ m s}^{-2}$ and comes to a stop. The total time of motion is 25 s. The average velocity is equal to 20 m s^{-1}. How long does the car move uniformly?

A. 20 s B. 15 s C. 10 s D. 50 s

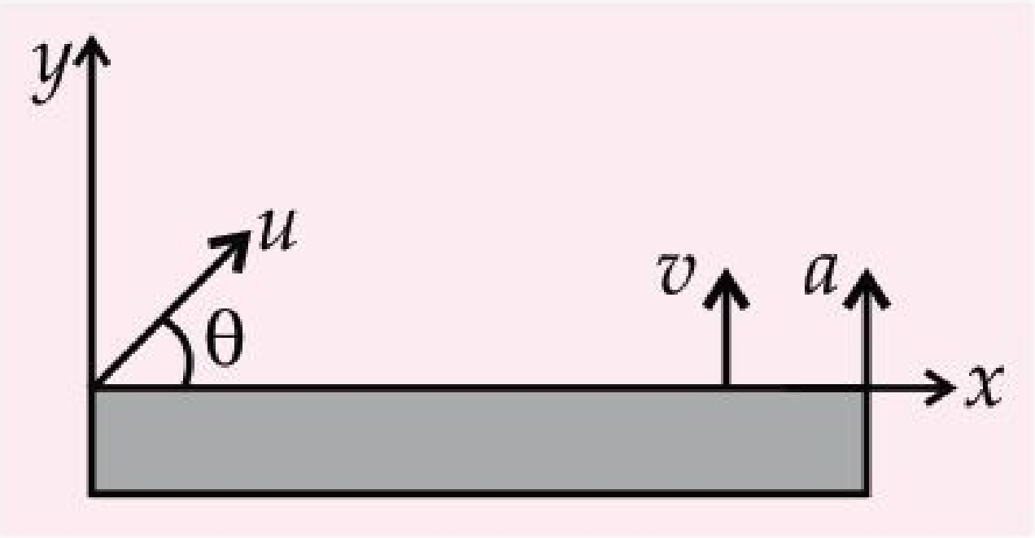
3. Two objects A and B are moving with constant velocity 10 m s^{-1} and 20 m s^{-1} along X axis and Y axis as shown in the figure. Find out the closest distance of approach between the two objects.



A. $2\sqrt{5}$ m B. $5\sqrt{5}$ m

C. $4\sqrt{5}$ m D. $7\sqrt{5}$ m

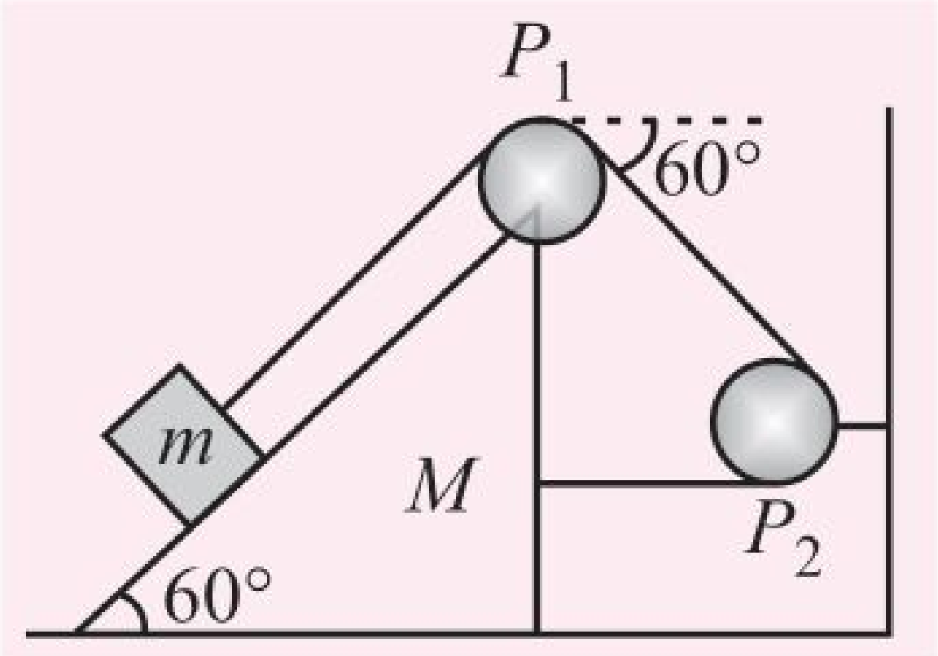
4. A horizontal platform is moving vertically upward with constant acceleration a. When velocity of the platform is v, a particle is projected from the platform with velocity u relative to the ground at an angle θ with the horizontal. Find the horizontal range of the particle on the platform.



A. $\dfrac{2u\cos\theta(u\sin\theta-v)}{g+a}$ B. $\dfrac{u\cos\theta(u\sin\theta-v)}{g+a}$

C. $\dfrac{u\cos\theta(u\sin\theta+v)}{g+a}$ D. $\dfrac{2u\cos\theta(u\sin\theta+v)}{g-a}$

5. In the arrangement shown in figure, the block of mass m = 2 kg lies on the wedge of mass M = 8 kg. The initial acceleration of the wedge, if the surfaces are smooth, is



A. $\dfrac{\sqrt{3}g}{23}\text{ m s}^{-2}$ B. $\dfrac{3\sqrt{3}g}{23}\text{ m s}^{-2}$

C. $\dfrac{3g}{23}\text{ m s}^{-2}$ D. $\dfrac{g}{23}\text{ m s}^{-2}$

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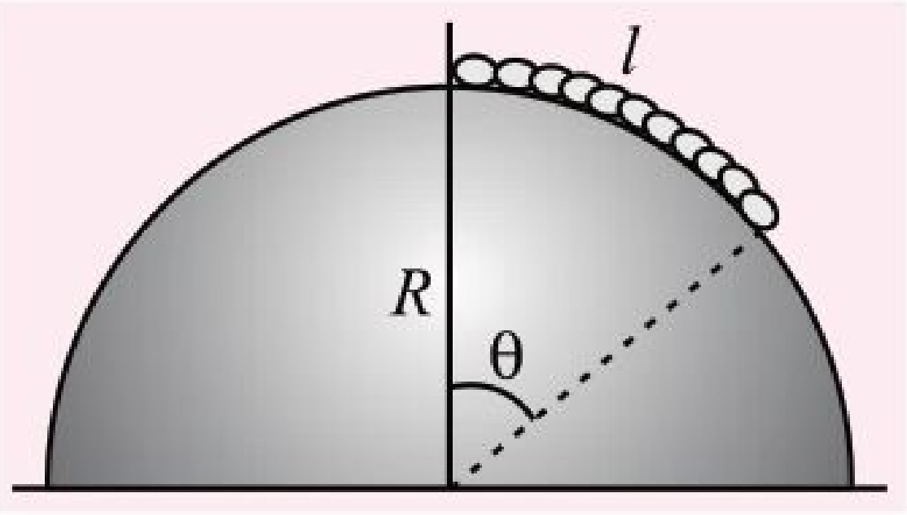
6. A chain of length l and mass m lies on the surface of a smooth sphere of radius $R > l$ with one end tied to the top of the sphere.



Find the gravitational potential energy of the chain with reference level at the centre of the sphere.

A. $mgR\sin\frac{l}{R}$ B. $mgR^2\sin\frac{l}{R}$

C. $\frac{mgR^2}{l}\sin\frac{R}{l}$ D. $\frac{mgR^2}{l}\sin\frac{l}{R}$

7. Two discs A and B are mounted coaxially on a vertical axle, have moments of inertia I and $2I$ respectively about the common axis. Disc A is imparted an initial angular velocity 2ω and kinetic energy K_A using the entire potential energy of a spring compressed by a distance x_1. Disc B is imparted an angular velocity ω and kinetic energy K_B by the same spring compressed by a distance x_2. Both the discs rotate in the clockwise direction initially. When disc B is brought in contact with disc A, they acquire a common angular velocity in time t. The average frictional torque on one disc by the other during this period and the new kinetic energy acquired by the system are respectively

A. $\frac{2I\omega}{3t}$ and $\frac{8}{3}K_B$ B. $\frac{9I\omega}{2t}$ and $\frac{8}{3}K_B$

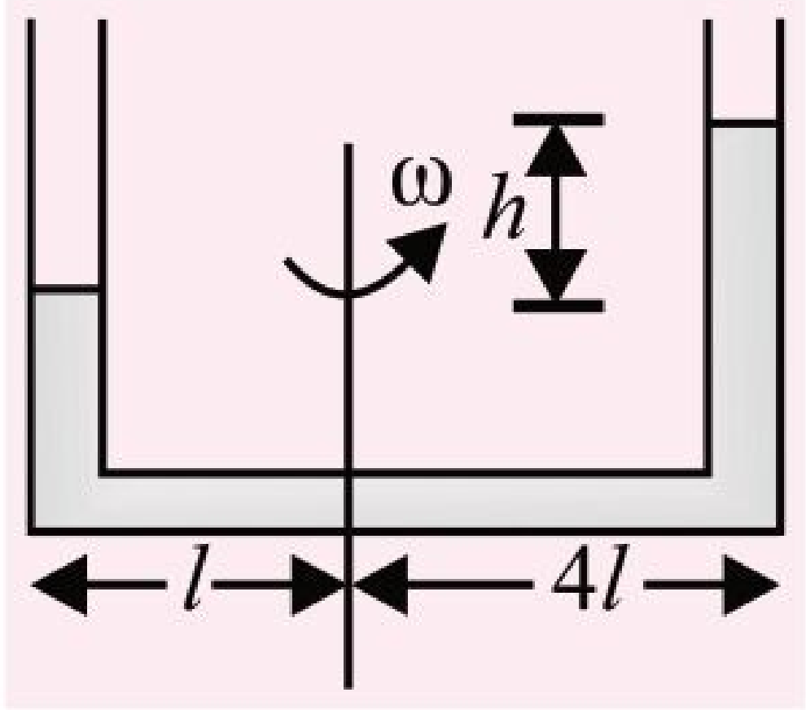
C. $\frac{9I\omega}{4t}$ and $\frac{4}{3}K_A$ D. $\frac{3I\omega}{2t}$ and $\frac{4}{3}K_A$

8. A horizontal tube of length 1 m closed at both ends contains an ideal gas of molecular weight M. The tube is rotated at a constant angular velocity 2 rad s^{-1} about a vertical axis passing through an end. Assuming T be the temperature of gas and it is uniform and constant. P_2 and P_1 denote the pressures at the free end and the fixed end respectively. R is the gas constant. Choose the correct relation.

A. $P_2 = P_1\left(\frac{2M}{RT}\right)$ B. $P_2 = P_1\left(\frac{2RT}{M}\right)$

C. $P_2 = P_1\, e^{\left(\frac{2M}{RT}\right)}$ D. $P_2 = P_1\, e^{\left(\frac{M}{2RT}\right)}$

9. A U-tube is rotating with angular velocity $\omega = \sqrt{\frac{g}{l}}$ as shown. What will be the difference in level of liquid in the two limbs?



A. $15l$ B. $2.5l$

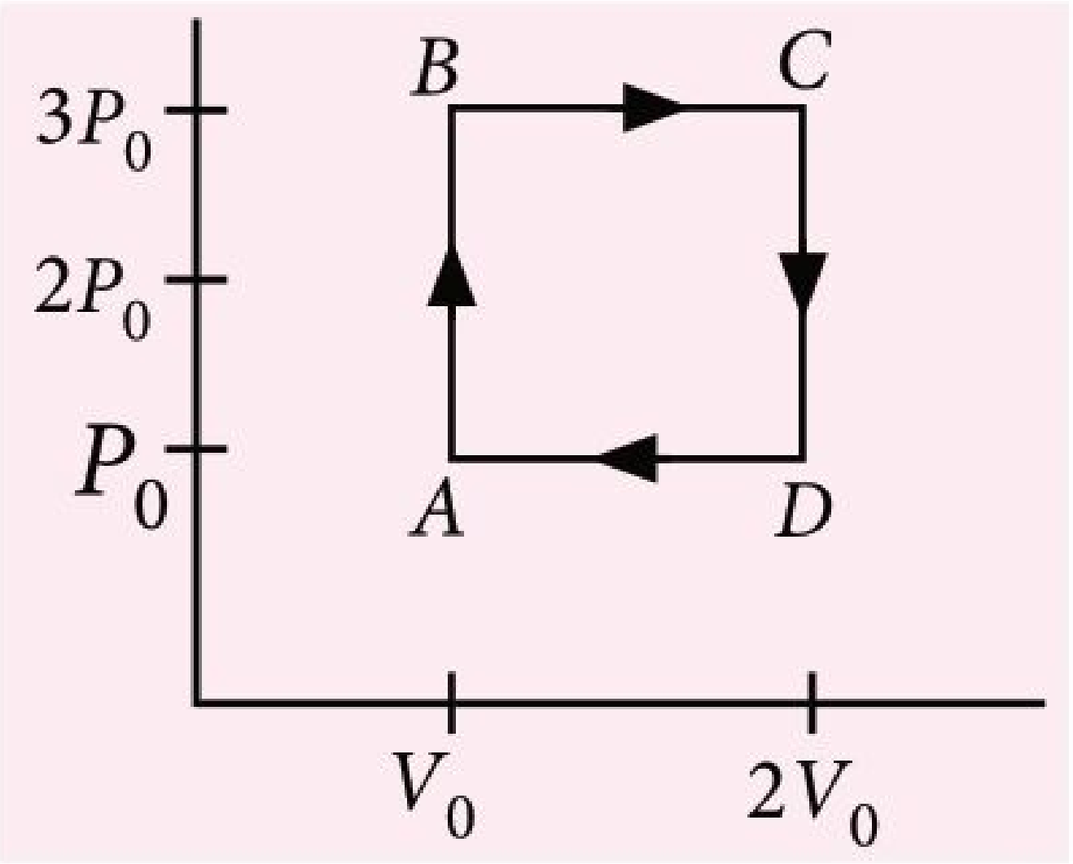
C. $8l$ D. $7.5l$

10. A disc of mass m and radius r is kept on a rough horizontal surface. A spring of spring constant k is attached at a distance a above the centre of the disc. Assuming that friction is sufficient for rolling, find the time period of oscillations.

A. $2\pi\sqrt{\frac{3mr^2}{2k(a+r)^2}}$ B. $\frac{1}{2\pi}\sqrt{\frac{3mr^2}{2k(a+r)^2}}$

C. $2\pi\sqrt{\frac{2mr^2}{k(a+r)^2}}$ D. $\frac{1}{2\pi}\sqrt{\frac{mr^2}{k(a+r)^2}}$

11. An engine operates by taking a monatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close to ________



A. 12% B. 15%

C. 19% D. 28%

12. The displacement of a particle is represented by the equation $y = \sin^3 \omega t$. The motion is

A. Non-periodic

B. Periodic but not simple harmonic

C. Simple harmonic with period $2\pi/\omega$

D. Simple harmonic with period π/ω.

13. An ideal gas of molar mass M is contained in a very tall vertical cylindrical column in the uniform gravitational field. Assuming the gas temperature to be T, the height at which the centre of gravity of the gas is located is (R : universal gas constant)

A. $\frac{RT}{g}$ B. $\frac{RT}{Mg}$ C. MgR D. RTg

14. A stationary tuning fork is in resonance with an air column in a pipe. If the tuning fork is moved with a speed of 2 m s^{-1} in front of the open end of the pipe and parallel to it, the length of the pipe should be changed for the resonance to occur with the moving tuning fork. If the speed of sound in air is 320 m s^{-1}, the smallest value of the percentage change required in the length of the pipe is

A. 0.125% B. 1.5%

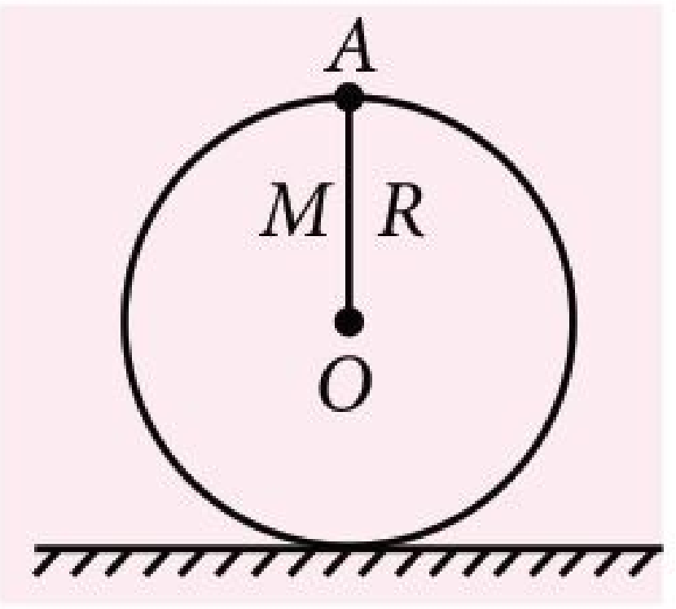
C. 0.25% D. 0.625%

15. When the observer moves towards the stationary source with velocity, V_1, the apparent frequency of emitted note is F_1. When the observer moves away from the source with velocity V_1, the apparent frequency is F_2. If V is the velocity of sound in air and $\frac{F_1}{F_2} = 2$, then $\frac{V}{V_1} = ?$

A. 2 B. 3 C. 4 D. 5

ACHIEVERS SECTION

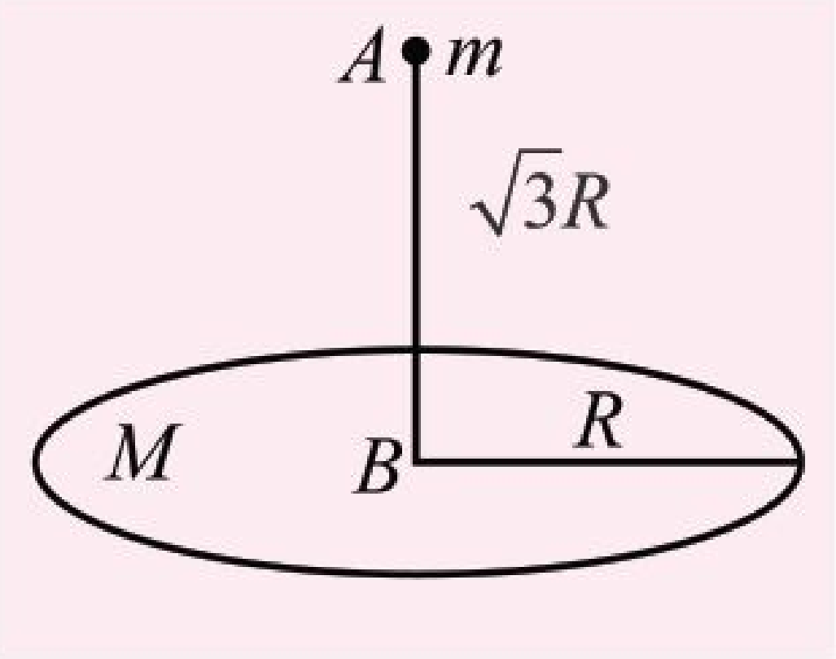
16. A rod of mass M has been fixed on a ring of same mass. The whole set-up has been placed on a rough surface. The system is gently displaced so that the ring starts rolling. Find the velocity of the centre of the ring when the rod becomes horizontal.
(Assume that length of the rod is equal to the radius of the ring)



A. $\sqrt{\frac{3gR}{10}}$ B. $\sqrt{\frac{3g}{10R}}$

C. $\sqrt{\frac{gR}{10}}$ D. $\sqrt{\frac{10R}{3g}}$

17. A circular ring of mass M and radius R, free to move, is placed in a gravity free space. A point mass m placed on the axis of the ring, at a distance $\sqrt{3}R$ from the centre of the ring, is released from rest. Find the velocity with which the point mass crosses the centre of ring.



A. $\sqrt{\frac{GM}{R(M+m)}}$ B. $\sqrt{\frac{GM^2}{R(M+m)}}$

C. $\sqrt{\frac{2GM}{R(M+m)}}$ D. $\sqrt{\frac{GM}{(M+m)}}$

18. Four balls of same masses are projected with the equal speeds at angles 15°, 30°, 60° and 75° with the horizontal direction from the ground. On the basis of given information, match the quantities of Column I with the angle of projection given in Column II.

	Column I		Column II
P.	Horizontal range will be maximum for angle	(i)	15°
Q.	The vertical height will be maximum for angle	(ii)	30°
R.	The time of flight will be minimum for angle	(iii)	60°
S.	The horizontal range will be minimum for angle	(iv)	75°

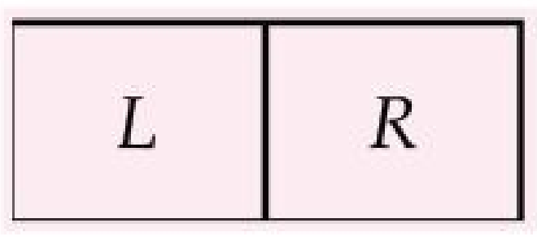
A. P-(i), (ii); Q-(i); R-(iv); S-(ii), (iii)
B. P-(ii), (iii); Q-(iv); R-(i); S-(i), (iv)
C. P-(iii), (iv); Q-(ii); R-(iii); S-(i), (ii)
D. P-(i), (iii); Q-(iii); R-(ii); S-(iii), (iv)

19. Two rods of equal lengths and equal cross-sectional areas are made of materials whose Young's modulii are in the ratio of 2:3. They are suspended and loaded with the same mass. When stretched and released, they will oscillate with time periods in the ratio of

A. $\sqrt{3} : \sqrt{2}$ B. $3 : 2$

C. $3\sqrt{3} : 2\sqrt{2}$ D. $9 : 4$

20. The figure shows two identical copper blocks of mass 1.5 kg. When they were not in contact, block L was at temperature 60°C and block R was at temperature 20°C. But, when the blocks bring in contact, they come to the equilibrium temperature 40°C. What is the net entropy change of the two block system during the irreversible process?
(Specific heat of copper = 386 J kg^{-1} K^{-1})



A. 2.4 J K^{-1} B. 3.6 J K^{-1}
C. 4.2 J K^{-1} D. 5.2 J K^{-1}

Darken your choice with HB Pencil

1.	Ⓐ Ⓑ Ⓒ Ⓓ	**5.**	Ⓐ Ⓑ Ⓒ Ⓓ	**9.**	Ⓐ Ⓑ Ⓒ Ⓓ	**13.**	Ⓐ Ⓑ Ⓒ Ⓓ	**17.**	Ⓐ Ⓑ Ⓒ Ⓓ
2.	Ⓐ Ⓑ Ⓒ Ⓓ	**6.**	Ⓐ Ⓑ Ⓒ Ⓓ	**10.**	Ⓐ Ⓑ Ⓒ Ⓓ	**14.**	Ⓐ Ⓑ Ⓒ Ⓓ	**18.**	Ⓐ Ⓑ Ⓒ Ⓓ
3.	Ⓐ Ⓑ Ⓒ Ⓓ	**7.**	Ⓐ Ⓑ Ⓒ Ⓓ	**11.**	Ⓐ Ⓑ Ⓒ Ⓓ	**15.**	Ⓐ Ⓑ Ⓒ Ⓓ	**19.**	Ⓐ Ⓑ Ⓒ Ⓓ
4.	Ⓐ Ⓑ Ⓒ Ⓓ	**8.**	Ⓐ Ⓑ Ⓒ Ⓓ	**12.**	Ⓐ Ⓑ Ⓒ Ⓓ	**16.**	Ⓐ Ⓑ Ⓒ Ⓓ	**20.**	Ⓐ Ⓑ Ⓒ Ⓓ

1. (D) : $v=\sqrt{\dfrac{T}{m}}=\left[\dfrac{m'g}{\dfrac{M}{l}}\right]^{1/2}=\left[\dfrac{m'lg}{M}\right]^{1/2}$

It follows from here,

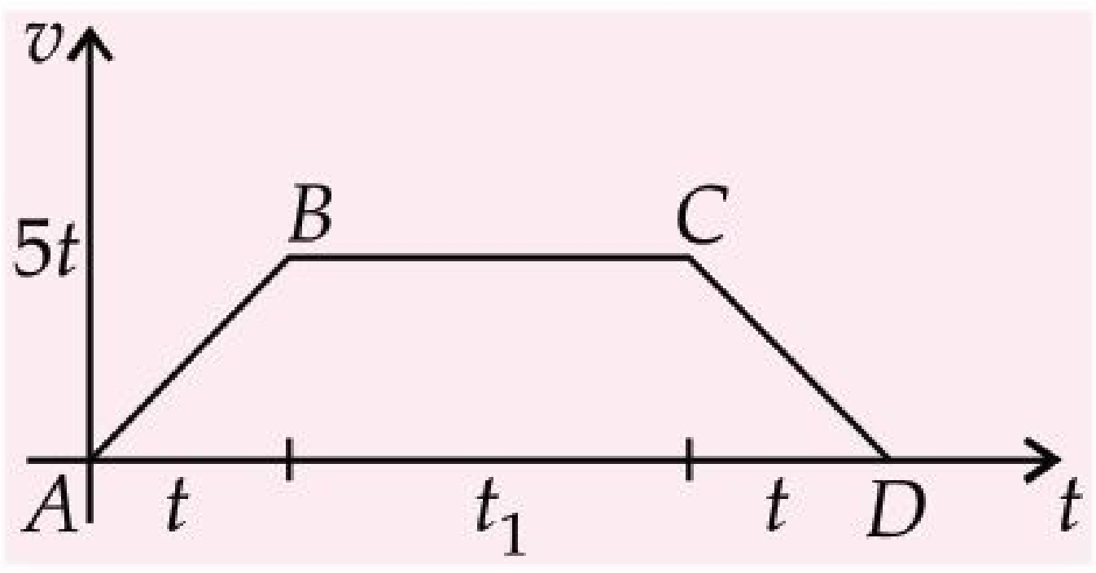
$$\frac{\Delta v}{v}=\frac{1}{2}\left[\frac{\Delta m'}{m'}+\frac{\Delta l}{l}+\frac{\Delta M}{M}\right]=\frac{1}{2}\left[\frac{0.1}{3.0}+\frac{0.001}{1.000}+\frac{0.1}{2.5}\right]$$

$$=\frac{1}{2}[0.03+0.001+0.04]=3.6\%$$

Percentage error in the measurement

$= 0.036 \times 100 = 3.6\%$

2. (B) : Velocity *vs* time graph for the given data will be as shown in the figure.



AB - Acceleration, say the time for acceleration is *t*.

BC - Uniform motion, say the time for uniform motion is t_1.

CD - Deceleration, time for deceleration motion will be *t* (Time of deceleration will be same as that of acceleration).

$\therefore$ Total time of motion $= 2t + t_1 = 25$ s (Given)

Area under the velocity *vs* time curve = Displacement

$$\frac{1}{2}5t^2+(25-2t)5t+\frac{1}{2}5t^2=\text{Displacement},$$

Displacement $= 125t - 5t^2$

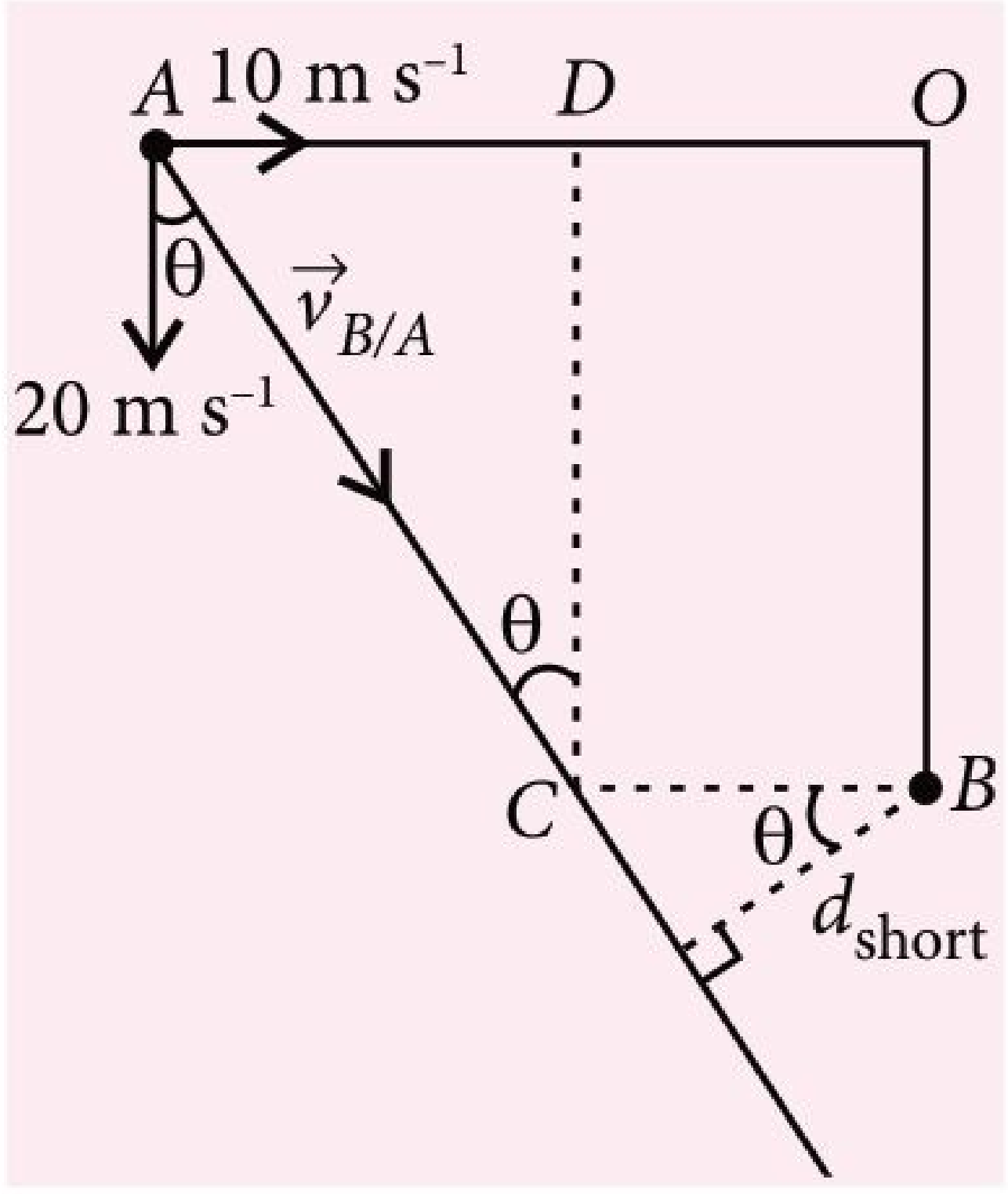
$$\text{Average velocity}=\frac{\text{Total displacement}}{\text{Total time}};\ 20=\frac{125t-5t^2}{25};$$

$5t^2 - 125t + 500 = 0$

$\therefore\ t = 5$ s ($t \neq 20$ since total time is 25 s)

$t_1 = 25 - 2t = 15$ s.

3. (C) : Velocity of *A* relative to *B* is directed along the line *AC* as shown.



$\tan\theta=\dfrac{10}{20}=\dfrac{1}{2}$ and from figure $\tan\theta=\dfrac{AD}{CD}=\dfrac{AD}{40}=\dfrac{1}{2}$

$\Rightarrow\ AD = 20$ m

$\Rightarrow\ DO = (30 - 20)$ m $= 10$ m

$\Rightarrow\ BC = DO = 10$ m

Closest distance of approach,

$$d_{\text{short}}=BC\cos\theta=10\cos\theta=\frac{10\times2}{\sqrt{5}}=4\sqrt{5}\text{ m}$$

4. (A) : Velocity of projectile relative to the ground,

$\vec{u}_{P/G}=(u\cos\theta)\hat{i}+(u\sin\theta)\hat{j}$

Acceleration of projectile relative to the ground,

$\vec{a}_{P/G}=(-g)\hat{j}$

Velocity of platform relative to the ground at the time of projection, $\vec{u}_{Pl/G}=(v)\hat{j}$

Acceleration of platform relative to the ground at the time of projection, $\vec{a}_{Pl/G}=(\vec{a})\hat{j}$

Motion of the particle with respect to the platform (platform is considered at rest)

$\vec{u}_{\text{rel}}=(u\cos\theta)\hat{i}+(u\sin\theta-v)\hat{j}=\vec{u}_{P/Pl}$

and $\vec{a}_{\text{rel}}=-(g+a)\hat{j}=\vec{a}_{P/Pl}$

$$s_{y,\text{rel}}=u_{y,\text{rel}}t+\frac{1}{2}a_{y,\text{rel}}t^2;$$

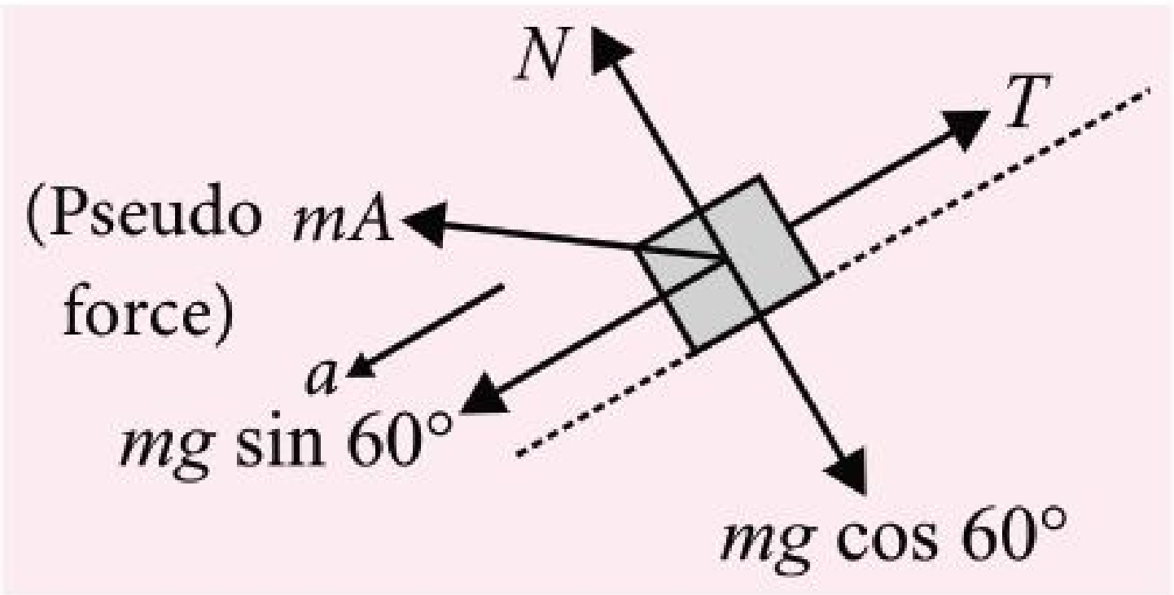
$$s_{y,\text{rel}}=(u\sin\theta-v)t-\frac{1}{2}(g+a)t^2$$

Flight completes when *y*-component of displacement of projectile relative to platform becomes zero.

$$0=(u\sin\theta-v)T-\frac{1}{2}(g+a)T^2\Rightarrow T=\frac{2(u\sin\theta-v)}{g+a}.$$

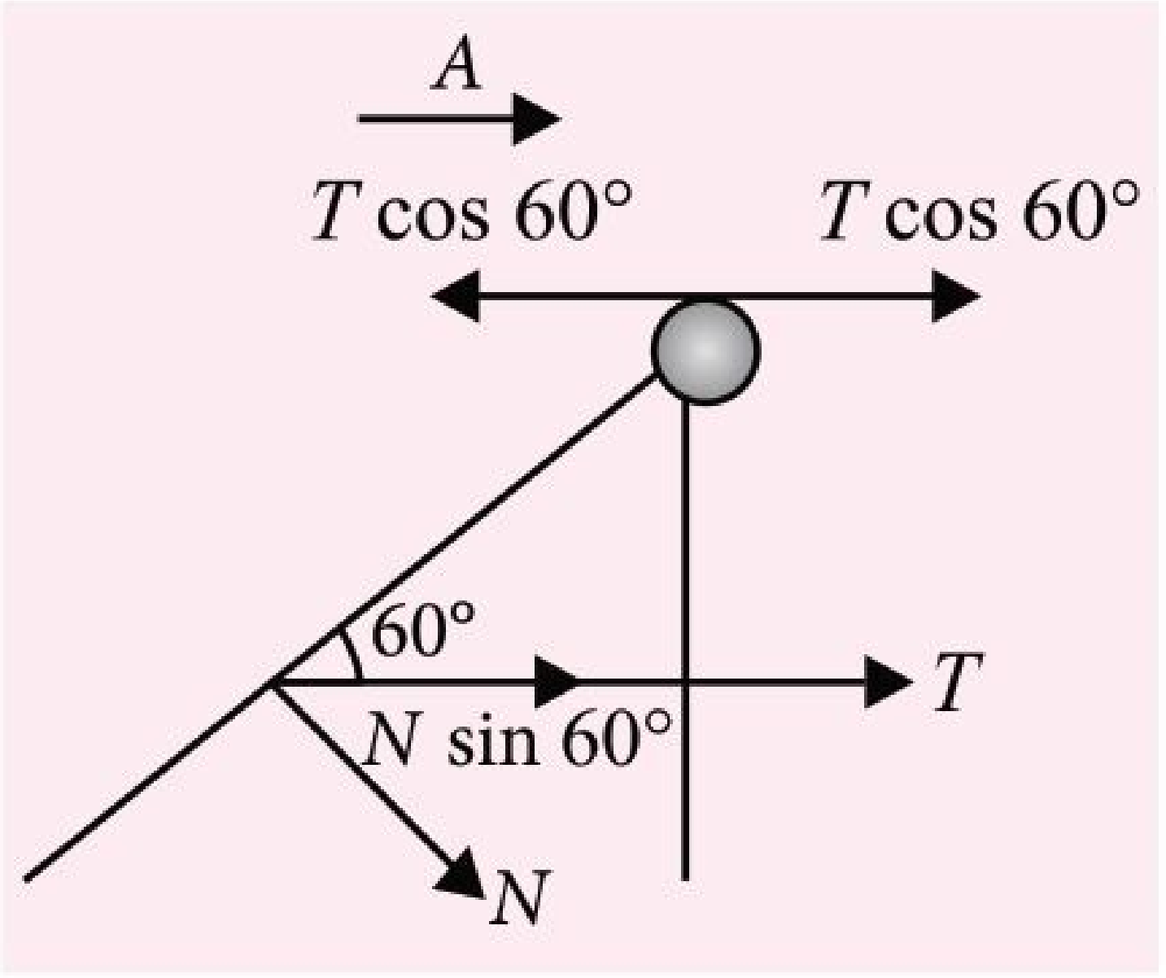
$$\text{Range, }R=(u\cos\theta)T=\frac{2u\cos\theta(u\sin\theta-v)}{g+a}.$$

5. (B) : If initial acceleration of *M* towards right is *A*, then acceleration of *m* w.r.t. *M* down the incline is



$$a=A(1+\cos\theta)=\frac{3A}{2}\qquad(\because\ \theta=60^\circ)$$

Equations of motion:



For $m,\ mg\dfrac{\sqrt{3}}{2}+mA\times\dfrac{1}{2}-T=m\left(\dfrac{3}{2}A\right)$

$$T=\frac{\sqrt{3}mg}{2}-mA\quad\text{...(i)}$$

Perpendicular to the plane,

$$N + mA\frac{\sqrt{3}}{2} = mg\frac{1}{2} \quad \text{...(ii)}$$

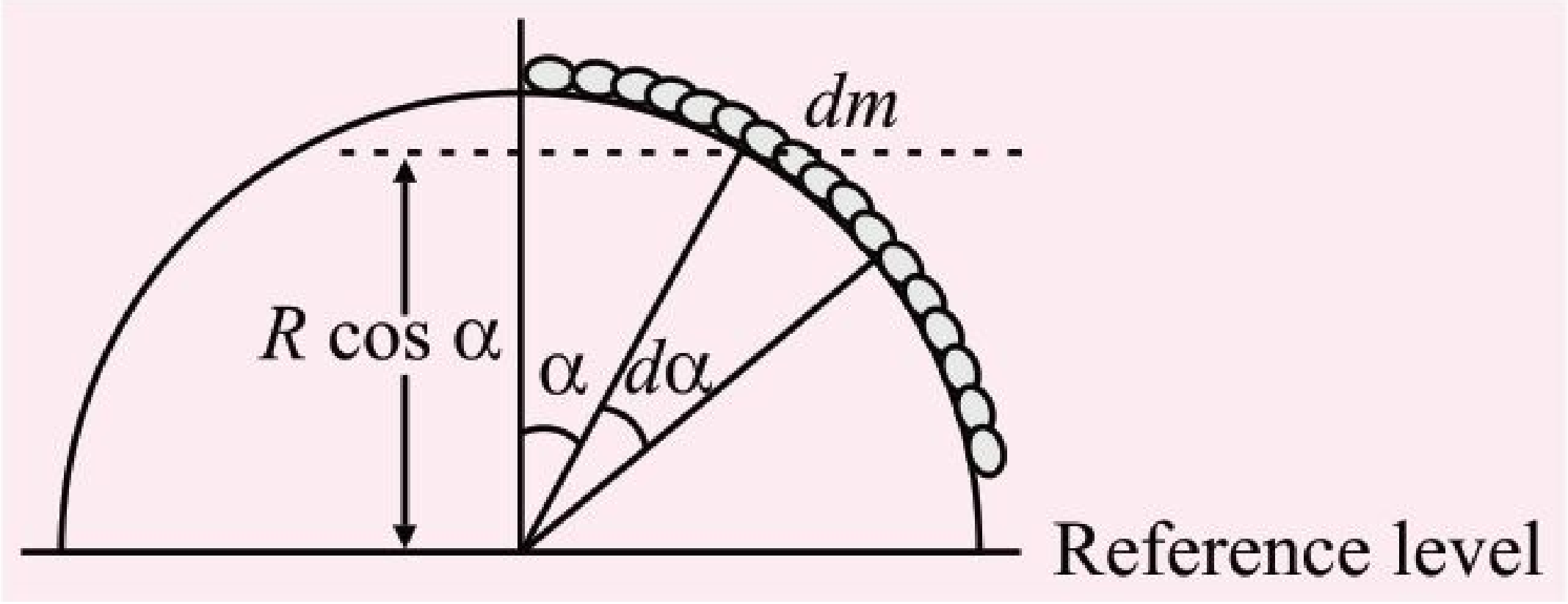
For $M, T + N\frac{\sqrt{3}}{2} = MA$ ...(iii)

From eqns. (i), (ii) and (iii), $A = \frac{3\sqrt{3}\,g}{23}\ \text{m s}^{-2}$

6. (D) : Let us consider a small element which makes an angle $d\alpha$ at the centre.

$$\therefore \quad dm = \frac{m}{l}Rd\alpha$$

Gravitational potential energy of dm with reference level at centre of the sphere = $dmgh$



$$= dm\, g\,(R\cos\alpha) = \frac{m}{l}Rd\alpha\; g\,R\cos\alpha$$

$\therefore$ Total gravitational potential energy,

$$U = \frac{mgR^2}{l}\int_0^{l/R}\cos\alpha\, d\alpha = \frac{mgR^2}{l}\sin\frac{l}{R}$$

7. (A) : $K_A = \frac{1}{2}I(2\omega)^2 = I\times\frac{4\omega^2}{2} = 2I\omega^2$

$$K_B = \frac{1}{2}\times 2I\omega^2 = I\omega^2$$

Using conservation of angular momentum,

$L_i = L_f$

$\therefore L_A + L_B = L_f$

$I\times 2\omega + 2I\times\omega = (2I + I)\omega'$

where ω' is the common angular velocity with which both discs rotates.

$\therefore \quad \omega' = 4\omega/3$

so, $\alpha = \frac{2\omega - 4\omega/3}{t} = \frac{2\omega}{3t}$

Torque, $\tau = I\alpha$ $\qquad \therefore \ \tau = \frac{2\omega I}{3t}$

Final KE, $K_f = \frac{1}{2}(I + 2I)\omega'^2 = \frac{1}{2}\times 3I\times\left(\frac{4\omega}{3}\right)^2$

$$= \frac{1}{2}\times 3I\times\frac{16\omega^2}{9} = \frac{1}{2}\times\frac{I}{3}\times 16\omega^2$$

$$= \frac{8I\omega^2}{3} = \frac{8}{3}K_B \qquad \left(\because K_B = \frac{1}{2}\times 2I\times\omega = I\omega\right)$$

8. (C) : Let us consider a thin slice of tube at a distance r and $r + dr$ with pressure difference dP.

So, $dP = \sigma r\omega^2\, dr$ ...(i)

where σ is mass density.

Now, according to ideal gas equation, $PV = RT$

or $P\frac{M}{\sigma} = RT$, or $M = \frac{\sigma RT}{P}$

or $\sigma = MP/RT$

Using equation (i), $dP = \frac{MP\omega^2}{RT}.rdr$

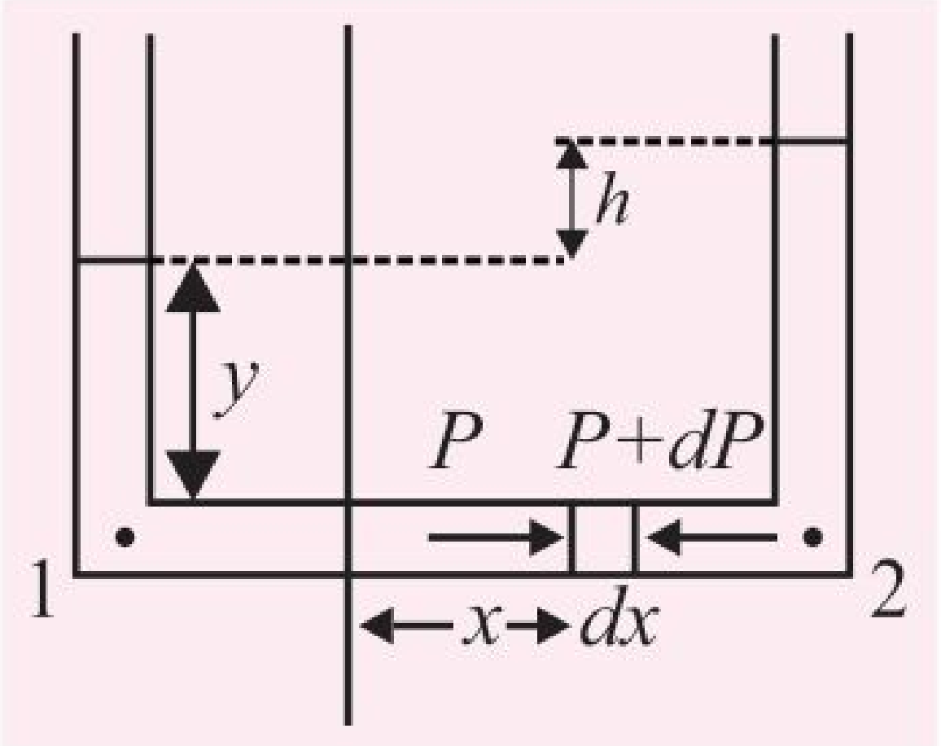
Integrating both sides, $\int_{P_1}^{P_2}\frac{dP}{P} = \frac{M\omega^2}{RT}\int_0^l rdr$

$$(\ln P_2 - \ln P_1) = \frac{M\omega^2}{RT}\cdot\frac{l^2}{2} \Rightarrow \ln\left(\frac{P_2}{P_1}\right) = \frac{M\times 2\times 2}{R\times T}\times\frac{1}{2}$$

$$\therefore P_2 = P_1 e^{\left(\frac{2M}{RT}\right)}$$

9. (D) : Say the cross-section of the tube is A. Let us consider an element of length dx at a distance x from the axis.

The mass of this element, $dm = (A\ dx)\rho$, where ρ is the density of the liquid.



Since the mass dm is in circular motion,

$\therefore$ Net force on it must be equal to $m\omega^2 x$ (centripetal force)

$(P + dP)A - PA = (dm)\omega^2 x$

$(dP)A = (A\ dx)\rho\omega^2 x$; $\int_P^{P_1} dP = \omega^2\rho\int_0^x x\ dx$

$$P_1 - P = \frac{\omega^2 x^2\rho}{2}$$

$$\therefore \quad P_1 = P + \frac{\omega^2 l^2\rho}{2} \text{ and } P_2 = P + \frac{16\omega^2 l^2\rho}{2}$$

$$P_2 - P_1 = \frac{15\omega^2 l^2\rho}{2} = \frac{15\,g\rho l}{2} \quad \text{... (i)}$$

P_1 and P_2 can also be written as

$P_1 = P_0 + y\rho g,$

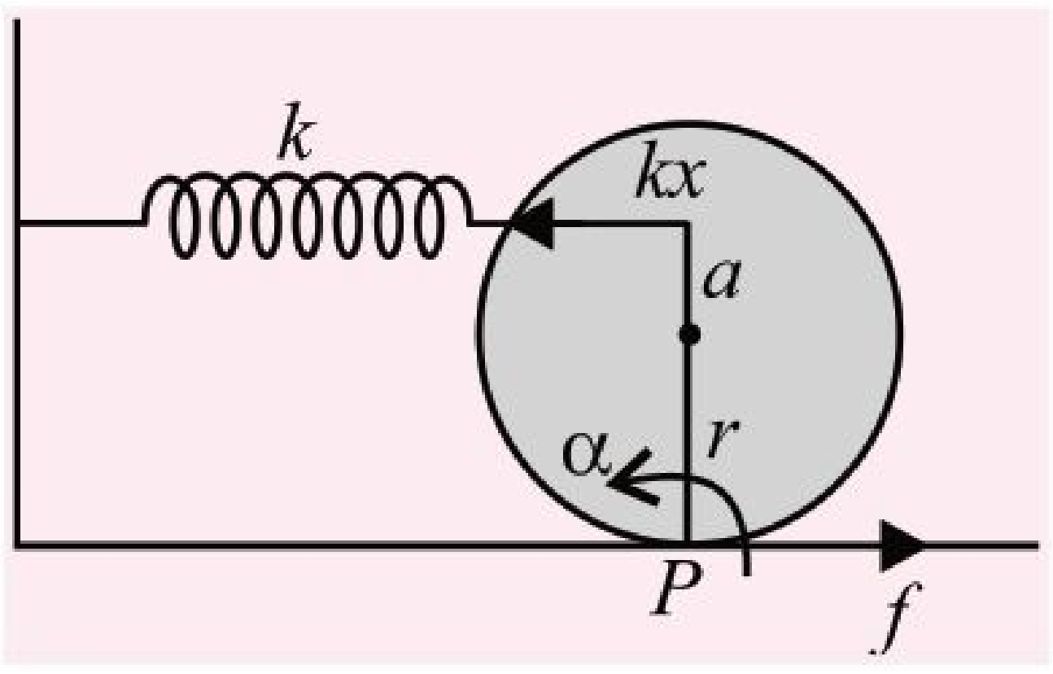
$P_2 = P_0 + (h + y)\rho g$

$\therefore \quad P_2 - P_1 = h\rho g$ ... (ii)

From eqns. (i) and (ii)

$$h\rho g = \frac{15\,g\rho l}{2};\ h = \frac{15}{2}l = 7.5\,l$$

10. (A) : The disc can be assumed to be in pure rotation about point P.



Net torque about point $P = I_P\alpha - kx\,(a + r)$

$= I_P\alpha$ ...(i)

where $x = (a + r)\theta$ and $I_P = \dfrac{mr^2}{2} + mr^2$

From eq. (i), we have,

$$-k(a + r)\theta\,(a + r) = I_P\alpha \Rightarrow -k(a+r)^2\theta = \frac{3}{2}mr^2\alpha$$

$$\Rightarrow \alpha = -\frac{2k\,(a+r)^2}{3mr^2}\theta \Rightarrow \omega = \sqrt{\frac{2k(a+r)^2}{3mr^2}}$$

$$T = 2\pi\sqrt{\frac{3mr^2}{2k(a+r)^2}}$$

11. (C) : Work done, ΔW = Area of loop

$= (3P_0 - P_0)\,(2V_0 - V_0) = 2P_0V_0$

$$Q_{AB} = nC_V(T_B - T_A) = \frac{3}{2}nR\,(T_B - T_A)$$

$$= \frac{3}{2}(3P_0 - P_0)V_0 = 3P_0V_0$$

$$Q_{BC} = nC_p(T_C - T_B) = \frac{5}{2}nR(T_C - T_B)$$

$$= \frac{5}{2}(3P_0)(2V_0 - V_0) = \frac{15}{2}P_0V_0 = 7.5\,P_0V_0$$

$$\text{Efficiency, } \eta = \frac{\text{Work done } (\Delta W)}{\text{Heat supplied } (\Delta Q)} \times 100$$

$$\eta = \frac{\Delta W}{\Delta Q_{AB} + \Delta Q_{BC}} \times 100$$

$$= \frac{2P_0V_0}{3P_0V_0 + 7.5P_0V_0} \times 100 = \frac{20}{105} = 19\%$$

12. (B) : Given, $y = \sin^3 \omega t$

We know that, $\sin 3A = 3\sin A - 4\sin^3 A$

$$\therefore\ y = \frac{3\sin\omega t - 4\sin 3\omega t}{4}$$

Differentiating w. r. t, t.

$$\text{So, } \frac{4dy}{dt} = 3\omega\cos\omega t - 4 \times 3\omega\cos 3\omega t$$

Again differentiating w. r. t, t

$$\frac{4d^2y}{dt^2} = -3\omega^2\sin\omega t + 12\,\omega\sin 3\omega t$$

$$\text{So, } \frac{d^2y}{dt^2} = \frac{-3\omega^2\sin\omega t + 12\omega^2\sin 3\omega t}{4}$$

Here, $\dfrac{d^2y}{dt^2}$ is not proportional to (y), so, it is not **SHM**.

As $\sin^3\omega t = (\sin\omega t)^3 = [\sin(\omega t + 2\pi)]^3$

So, the expression involves sine function, hence it will be periodic with period of $2\pi/\omega$.

13. (B) : Consider a gas layer of elemental thickness dh at a height h from the base of the cylinder.

If $P + dP$ and P are the pressure at the upper and lower surface of the elemental layer, then for equilibrium of this layer, $(P + dP)A + (dm)g = PA$

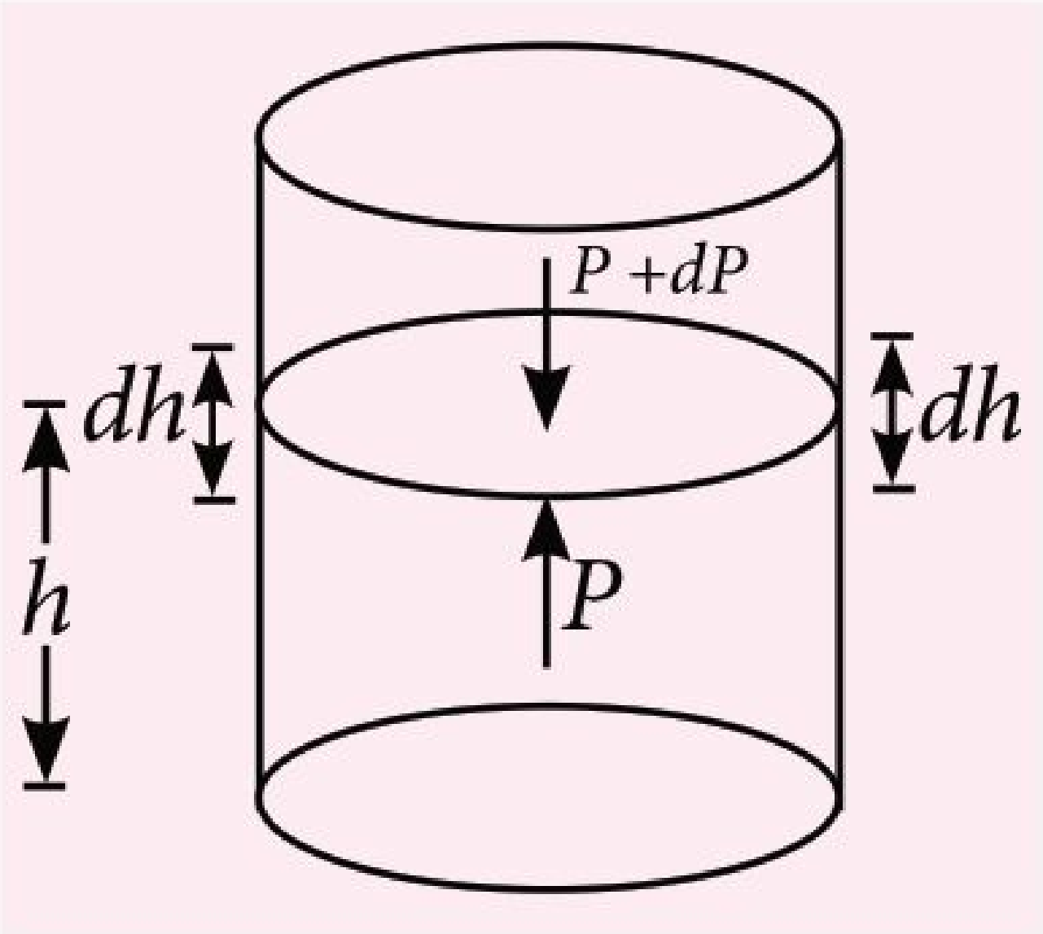
where dm is the mass of the elemental layer.

$\therefore$ $(P + dP)A + (\rho A dh)g = PA$ $(\because dm = \rho Adh)$

or $dP = -\rho g dh$ ...(i)

Now, from equation of an ideal gas

$PV = nRT$



or $PV = \dfrac{m}{M}RT$

or $P = \dfrac{m}{V}\dfrac{RT}{M}$

or $P = \rho\dfrac{RT}{M}$

Molar mass M and temperature T of the given gas is constant, thus we can write $dP = \dfrac{RT}{M}d\rho$

Putting this value in eq (i), we have

mtG

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$$-\rho g dh = \frac{RT}{M} d\rho \text{ or } \frac{d\rho}{\rho} = -\frac{Mg}{RT} dh$$

Integrating both sides, $\int_{\rho_0}^{\rho} \frac{d\rho}{\rho} = -\frac{Mg}{RT} \int_0^h dh$

$$\therefore \quad \rho = \rho_0 e^{-\left(\frac{Mgh}{RT}\right)} \qquad \text{...(ii)}$$

Now, given that gravitational field is constant, the centre of gravity and centre of mass lies at the same point. The location of centre of mass will be given as,

$$\text{C.M.} = \frac{\int_0^{\infty} h\,dm}{\int_0^{\infty} dm} = \frac{\int_0^{\infty} h\rho A\,dh}{\int_0^{\infty} \rho A\,dh} = \frac{\int_0^{\infty} h\rho\,dh}{\int_0^{\infty} \rho\,dh}$$

($\because$ surface area A is constant)

Now putting the value of ρ from eq (ii),

$$\text{C.M.} = \frac{\int_0^{\infty} h\rho_0 e^{\left(-\frac{Mgh}{RT}\right)} dh}{\int_0^{\infty} \rho_0 e^{\left(-\frac{Mgh}{RT}\right)} dh} = \frac{\int_0^{\infty} h e^{\left(-\frac{Mgh}{RT}\right)} dh}{\int_0^{\infty} e^{\left(-\frac{Mgh}{RT}\right)} dh} = \frac{RT}{Mg}$$

14. (D) : For resonance to occur, the frequency should be, $f = \frac{nV}{4L}$, where n is a positive odd integer.

Now let the initial resonant frequency be $f_0 = \frac{V}{4L_1}$

where L_1 is the initial length of the tube.

Now, since the fork is moving towards or away from the tube, the new frequency

$$f' = \left(\frac{V}{V \pm V_s}\right) f_0 = \left(\frac{320}{320 \pm 2}\right) f_0$$

$$= \left(\frac{320}{318}\right) f_0 \text{ or } \left(\frac{320}{322}\right) f_0 = \frac{320}{318}\frac{V}{4L_1} \text{ or } \frac{320}{322}\frac{V}{4L_1}$$

∴ The new length, $L_2 = \frac{V}{4f'}$

$$= \frac{V \times 318 \times 4L_1}{4 \times 320 \times V} \text{ or } \frac{322 \times 4L_1 V}{320 \times 4V}$$

$$L_2 = \frac{318}{320} L_1 \text{ or } \frac{322}{320} L_1$$

∴ Fractional change in length, $\frac{\Delta L}{L_1} = 6.25 \times 10^{-3}$

Percentage change in length $= \frac{\Delta L}{L} \times 100 = 0.625\%$

15. (B) : When the observer moves towards the stationary source, apparent frequency of emitted note,

$$F_1 = \left(\frac{V + V_1}{V}\right) n \qquad \text{...(i)}$$

When the observer moves away from the stationary source, apparent frequency of emitted note

$$F_2 = \left(\frac{V - V_1}{V}\right) n \qquad \text{...(ii)}$$

Dividing eqn. (i) by eqn. (ii), we get

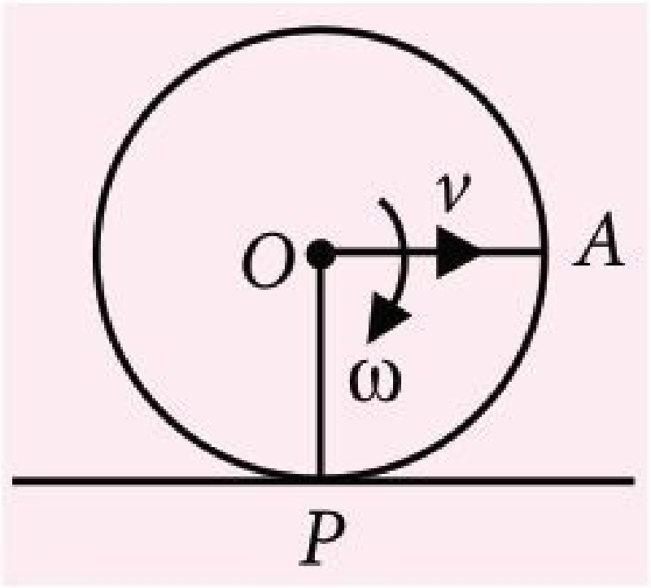
$$\frac{F_1}{F_2} = \frac{V + V_1}{V - V_1} \quad \because \frac{F_1}{F_2} = 2 \text{ (given)} \quad \therefore \frac{V + V_1}{V - V_1} = 2$$

$$\Rightarrow V + V_1 = 2V - 2V_1 \Rightarrow V = 3V_1 \text{ or } \frac{V}{V_1} = 3$$

16. (A) : Loss of $\text{P.E.} = Mg\frac{R}{2}$

Gain in $\text{K.E.} = \frac{1}{2} I_P \omega^2$ (Using concept of IAR)

Point P is instantaneously at rest. For moment of inertia of rod about P,

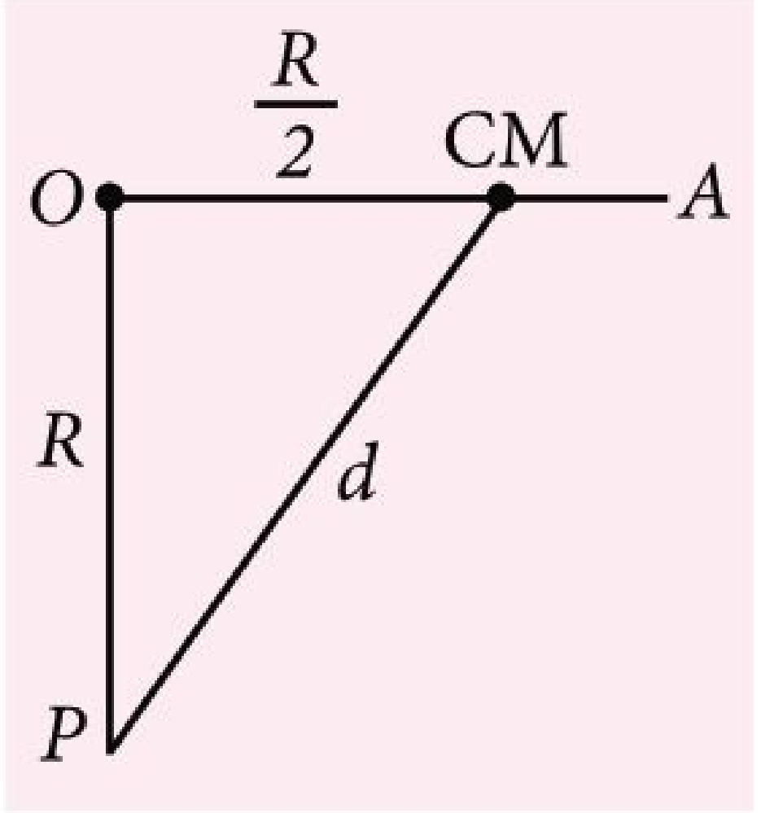


$$d = \sqrt{\frac{R^2}{4} + R^2}, \; I_{CM} = \frac{MR^2}{12}$$

$$\therefore \; I_{rod} = \frac{MR^2}{12} + M\left(\frac{R^2}{4} + R^2\right)$$

$$I_{ring} = I_{cm} + Md^2$$

$$I_{ring} = MR^2 + MR^2$$



Moment of inertia of the system about instantaneous axis of rotation is

$$I_P = I_{ring} + I_{rod}$$

$$= (MR^2 + MR^2) + \left(\frac{MR^2}{12} + M\left(\frac{R^2}{4} + R^2\right)\right)$$

$$= 2MR^2 + \frac{16MR^2}{12} = 2MR^2 + \frac{4}{3}MR^2 = \frac{10}{3}MR^2$$

Loss of potential energy = Gain in kinetic energy

$$Mg\frac{R}{2} = \frac{1}{2}\left(\frac{10}{3}MR^2\right)\omega^2 \Rightarrow \omega = \sqrt{\frac{3g}{10R}}$$

Now, velocity of centre of mass is given by, $v = R\omega$

$$\therefore v = \sqrt{\frac{3gR}{10}}$$

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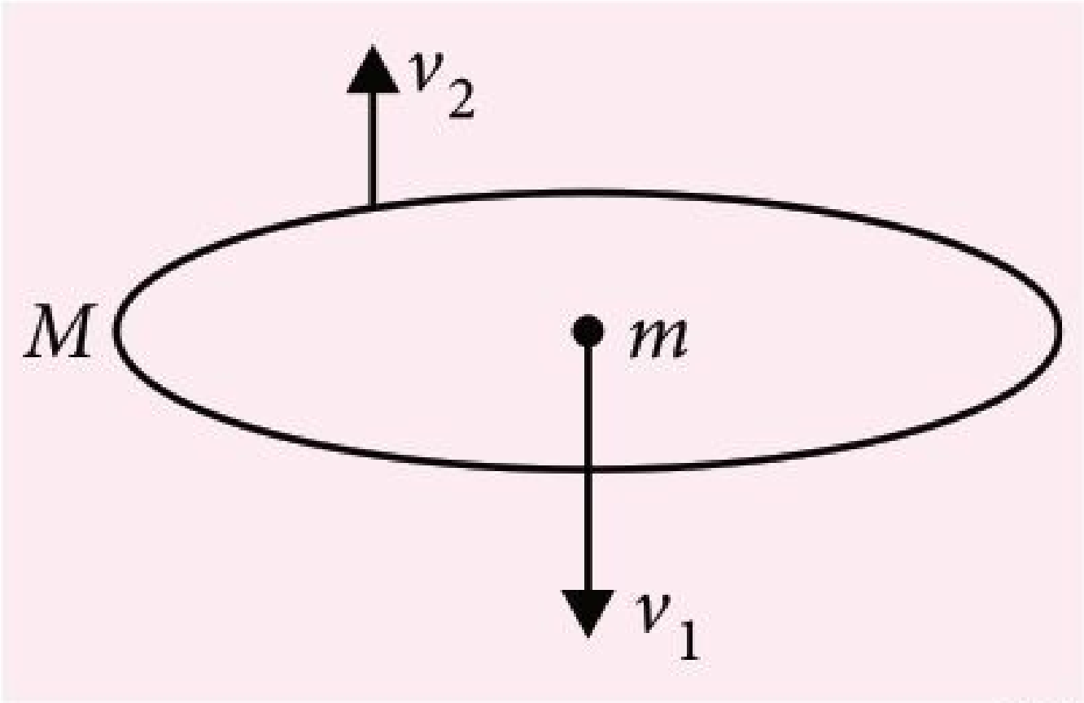
17. (B) : Net force on the system is zero, thus linear momentum of the system is conserved.



$0 + 0 = Mv_2 - mv_1$,

$\therefore Mv_2 = mv_1$ ...(i)

Applying conservation of energy,

$$mV_A + 0 + 0 = mV_B + \frac{1}{2}mv_1^2 + \frac{1}{2}Mv_2^2 \quad \text{...(ii)}$$

where V_A and V_B are the potential due to ring at A and B.

Potential due to a ring on its axis, $V = \frac{-GM}{\sqrt{R^2 + r^2}}$

$$\therefore \quad V_A = \frac{-GM}{\sqrt{R^2 + (\sqrt{3}R)^2}} = \frac{-GM}{2R},\ V_B = \frac{-GM}{\sqrt{R^2 + 0}} = \frac{-GM}{R}$$

From eq. (ii), we have

$$\frac{-mGM}{2R} = \frac{-mGM}{R} + \frac{1}{2}mv_1^2 + \frac{1}{2}Mv_2^2$$

$$\text{or} \quad \frac{GmM}{R} = mv_1^2 + Mv_2^2 \quad \text{...(iii)}$$

Putting $v_2 = \frac{mv_1}{M}$ in equation (iii), we get

$$\frac{GmM}{R} = mv_1^2 + \frac{Mm^2v_1^2}{M^2} \Rightarrow \frac{GM}{R} = v_1^2\left(1 + \frac{m}{M}\right)$$

$$\Rightarrow \quad v_1 = \sqrt{\frac{GM^2}{R(M+m)}}$$

18. (B) : $R = \frac{u^2 \sin 2\theta}{g}, h = \frac{u^2 \sin^2\theta}{2g}, T = \frac{2u\sin\theta}{g}$

For θ = 15°	For θ = 30°
$R = \frac{u^2 \sin 30°}{g} = 0.5u^2/g$	$R = \frac{u^2 \sin 60°}{g} = 0.866u^2/g$
$H = \frac{u^2 \sin^2 15°}{2g} = 0.033u^2/g$	$H = \frac{u^2 \sin^2 30°}{2g} = 0.125u^2/g$
$T = \frac{2u\sin 15°}{g} = 0.52u/g$	$T = \frac{2u\sin 30°}{g} = u/g$

For θ = 60°	For θ = 75°
$R = \frac{u^2 \sin 120°}{g} = 0.866u^2/g$	$R = \frac{u^2 \sin 150°}{g} = 0.5u^2/g$
$H = \frac{u^2 \sin^2 60°}{2g} = 0.375u^2/g$	$H = \frac{u^2 \sin^2 75°}{2g} = 0.466u^2/g$
$T = \frac{2u\sin 60°}{g} = 1.73u/g$	$T = \frac{2u\sin 75°}{g} = 1.93u/g$

So, R is maximum for 60° and 30° both.
H is maximum for 75°. T is minimum for 15°.
R is minimum for 15° and 75°.
$\therefore$ P-(ii), (iii); Q-(iv); R-(i); S-(i);(iv)

19. (A) : Given that, $L_1 = L_2 = L$, $A_1 = A_2 = A$ and $Y_1 : Y_2 = 2 : 3$

Let mass of the load is m.

$$Y = \frac{FL}{Al} = \frac{mgL}{Al}$$

Force constant, $k = \frac{F}{l} = \frac{mg}{l} = \frac{YA}{L}$

So, time period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{mL}{YA}}$

Here $T \propto \frac{1}{\sqrt{Y}}$, $\therefore \frac{T_1}{T_2} = \sqrt{\frac{Y_2}{Y_1}} = \sqrt{\frac{3}{2}}$

20. (A) : The entropy change of the block L is

$$\Delta S_L = (1.5\text{ kg})(386\text{ J kg}^{-1}\text{ K}^{-1})\int_{333\text{ K}}^{313\text{ K}} \frac{dT}{T}$$

$$= (1.5\text{ kg})(386\text{ J kg}^{-1}\text{ K}^{-1})\ln\frac{313\text{ K}}{333\text{ K}} = -35.8\text{ J K}^{-1}$$

The entropy change of the block R is

$$\Delta S_R = (1.5\text{ kg})(386\text{ J kg}^{-1}\text{ K}^{-1})\int_{293\text{ K}}^{313\text{ K}} \frac{dT}{T}$$

$$= (1.5\text{ kg})(386\text{ J kg}^{-1}\text{ K}^{-1})\ln\left(\frac{313\text{ K}}{293\text{ K}}\right) = +38.2\text{ J K}^{-1}$$

Thus, the net entropy change for the two block system during irreversible process is

$\Delta S_{\text{irrev}} = \Delta S_L + \Delta S_R = -35.8\text{ J K}^{-1} + 38.2\text{ J K}^{-1} = 2.4\text{ J K}^{-1}$

For other sections/subjects please refer to Chemistry Today and Biology Today

◆

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CLASS XII

SYLLABUS*

Section – 1 : *Physics* : Electricity and Magnetism, Electromagnetic Induction, Alternating current, Electromagnetic waves, Optics, Modern Physics, Semiconductor Electronics, Communication Systems.

Chemistry : Solid State, Solutions, Electrochemistry, Chemical Kinetics, Surface Chemistry, General Principles and Processes of Isolation of Elements, *p*-Block Elements (Group 15 to 18), *d*- & *f*-Block Elements, Coordination Compounds, Haloalkanes and Haloarenes, Alcohols, Phenols and Ethers, Aldehydes, Ketones and Carboxylic Acids, Amines, Biomolecules, Polymers, Chemistry in Everyday Life.

Total Questions : 50 Time : 1 hr.

PATTERN & MARKING SCHEME

Section	(1) Physics & Chemistry	(2) Achievers Section	(3) Mathematics or Biology
No. of Questions	25	5	20
Marks per Ques.	1	3	1

Section – 2 : Higher Order Thinking Questions - Syllabus as per Section – 1.

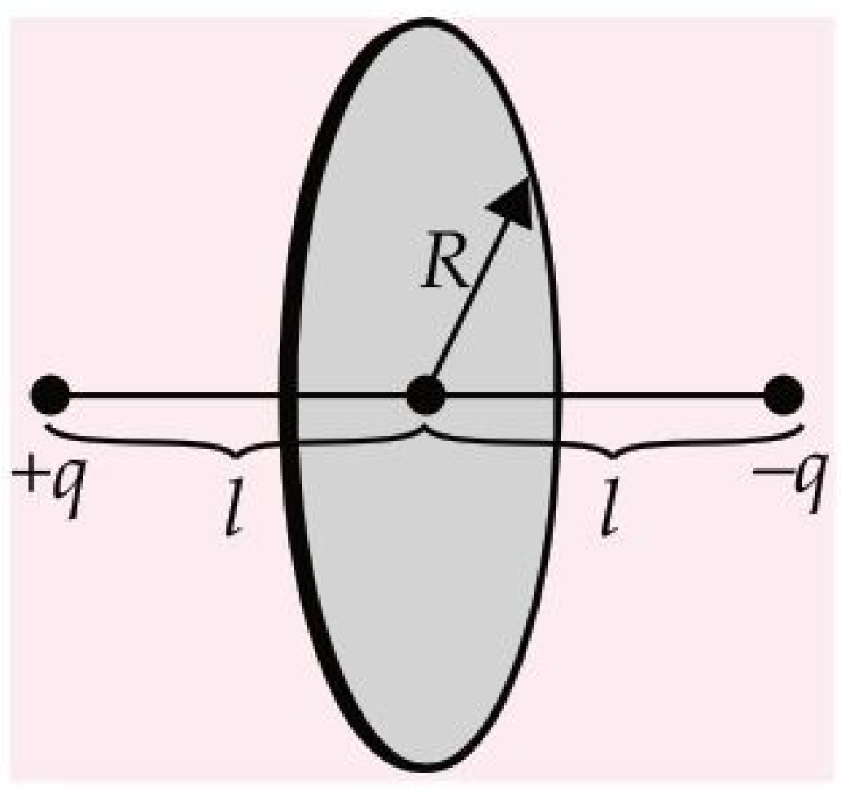
Section – 3 : Relations and Functions, Inverse Trigonometric Functions, Matrices and Determinants, Continuity and Differentiability, Application of Derivatives, Integrals, Application of Integrals, Differential Equations, Vector Algebra, Three Dimensional Geometry, Probability, Linear Programming.

OR

Section – 3 : Reproduction, Genetics and Evolution, Biology in Human Welfare, Biotechnology, Ecology.

Practice Questions

1. Two point charges q and $-q$ are separated by the distance $2l$ as shown in figure. Find the flux of the electric field strength vector across a circle of radius R.



A. $\frac{q}{\varepsilon_0}\left[1-\frac{l}{\sqrt{l^2+R^2}}\right]$ B. $\frac{q}{\varepsilon_0}\left[1+\frac{l}{\sqrt{l^2+R^2}}\right]$

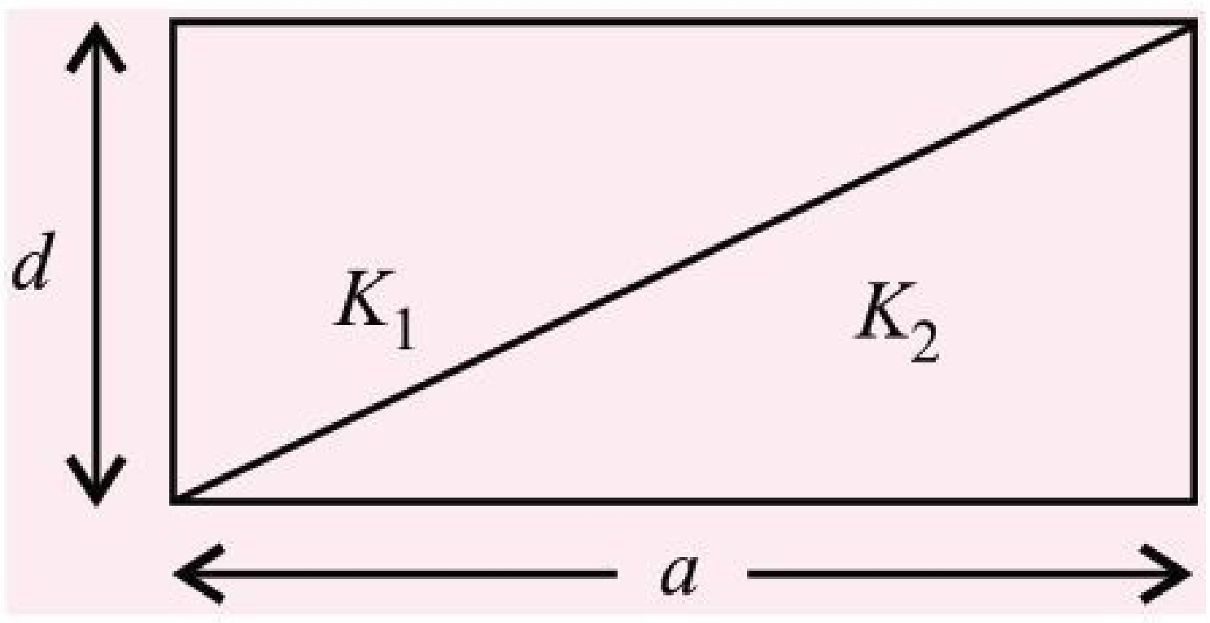
C. $\frac{q}{\varepsilon_0}\left[1+\frac{1}{\sqrt{l^2+R^2}}\right]$ D. $\frac{q}{\varepsilon_0}\left[1-\frac{2l}{\sqrt{l^2+R^2}}\right]$

2. A large insulating thick sheet of thickness $2d$ carries a uniform charge per unit volume ρ. A particle of mass m, carrying a charge q of sign opposite to that of the sheet is released from the surface of the sheet. The sheet does not offer any mechanical resistance to the motion of the particle. Find the oscillation frequency υ of the particle inside the sheet.

A. $\upsilon=\frac{1}{2\pi}\sqrt{\frac{q\rho}{m\varepsilon_0}}$ B. $\upsilon=\frac{1}{2\pi}\sqrt{\frac{2q\rho}{m\varepsilon_0}}$

C. $\upsilon=\frac{1}{4\pi}\sqrt{\frac{q\rho}{m\varepsilon_0}}$ D. $\upsilon=\frac{1}{4\pi}\sqrt{\frac{2q\rho}{m\varepsilon_0}}$

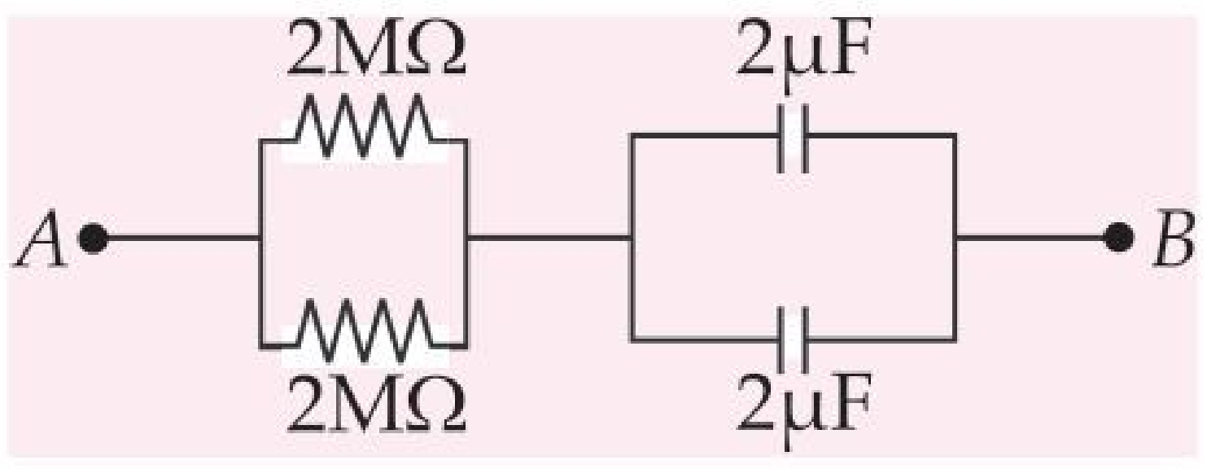
3. A parallel plate capacitor having square plates of side a is filled with dielectric of dielectric constant K_1 and K_2 as shown. The separation between the plates is d. Find the capacitance.



A. $\frac{K_1K_2\varepsilon_0a^2}{d(K_1+K_2)}\ln\frac{K_1}{K_2}$ B. $\frac{K_1K_2\varepsilon_0a^2}{2d(K_1+K_2)}\ln\frac{K_1}{K_2}$

C. $\frac{K_1K_2\varepsilon_0a^2}{d(K_1-K_2)}\ln\frac{K_1}{K_2}$ D. $\frac{K_1K_2\varepsilon_0a^2}{d(K_1-K_2)}\ln\frac{K_2}{K_1}$

4. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in seconds) does the voltage across them become 4 V?
[Take : $\ln 5 = 1.6$, $\ln 3 = 1.1$]



A. 2 B. 4 C. 5 D. 10

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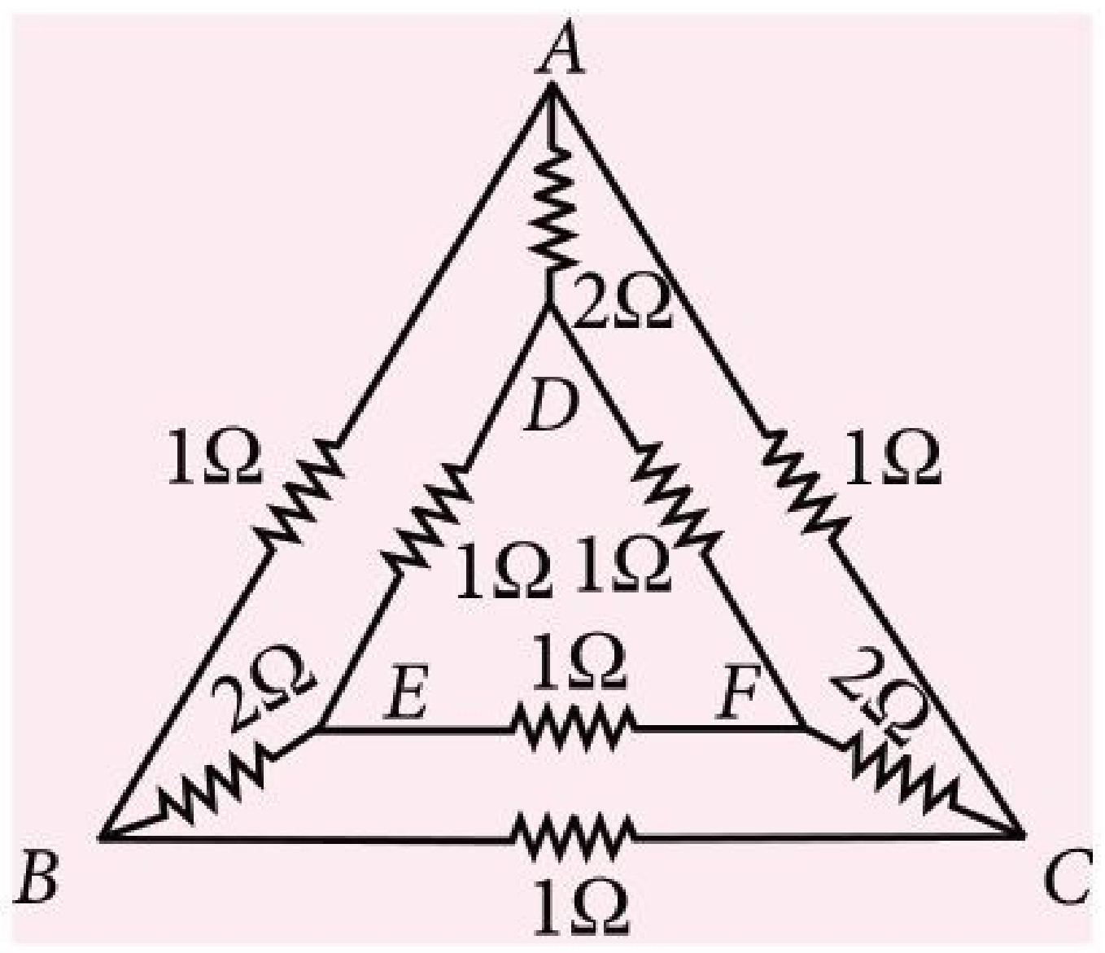
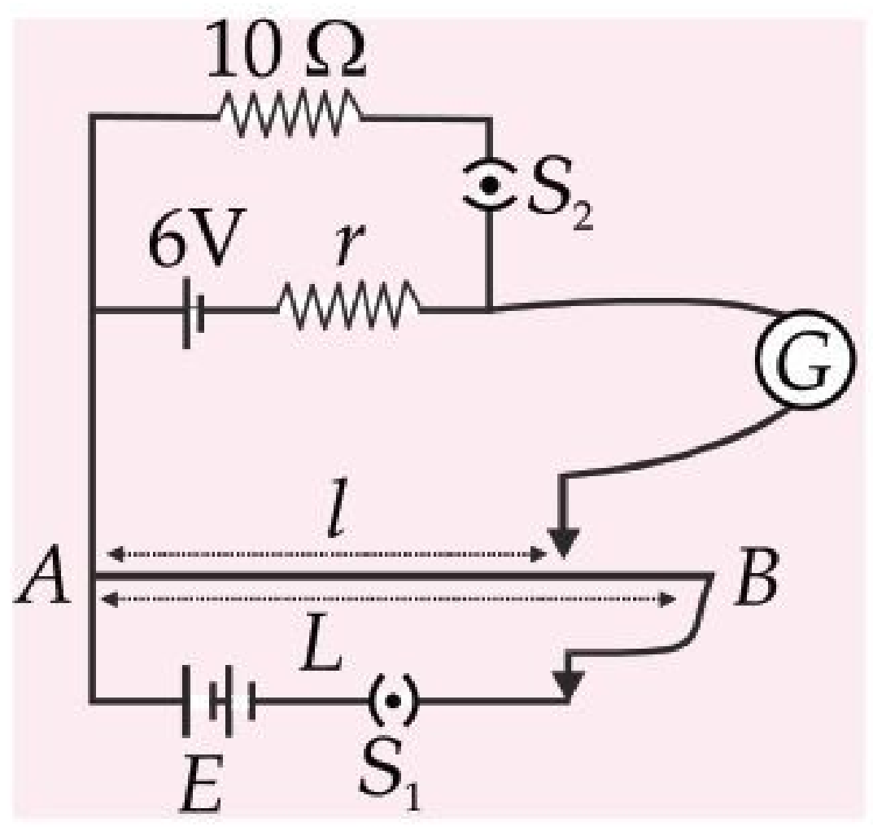
5. A network of nine conductors connects six points A, B, C, D, E and F as shown in figure. The figure denotes resistances in ohms. Find the equivalent resistance between A and D.



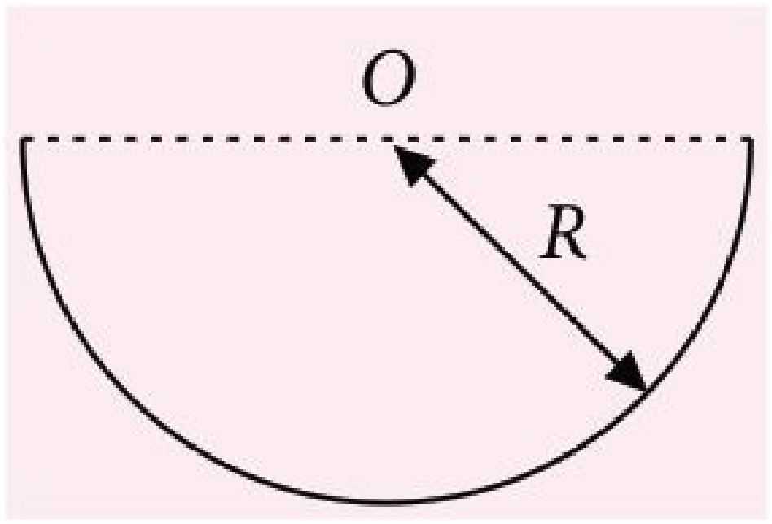
A. 4 Ω B. 5 Ω C. 1 Ω D. 2 Ω

6. In the arrangement shown in figure when the switch S_2 is open, the galvanometer shows no deflection for $\ell = \frac{L}{2}$. When the switch S_2 is closed, the galvanometer shows no deflection for $\ell = \frac{5L}{12}$. The internal resistance (r) of 6 V cell, and the emf E of the other battery are respectively



A. 3 Ω, 8 V B. 2 Ω, 12 V
C. 2 Ω, 24 V D. 3 Ω, 12 V

7. A current I flows in a long straight wire with its cross-section having the form of a half ring of radius R as shown in figure.
O is the centre of its mid-section perpendicular to its length. Assume the wire extends to infinite length on either side of the mid-section. Then the magnetic induction field B at the centre O will be



A. $B = \frac{\mu_0 I}{\pi R}$ B. $B = \frac{\mu_0 I}{2\pi R}$

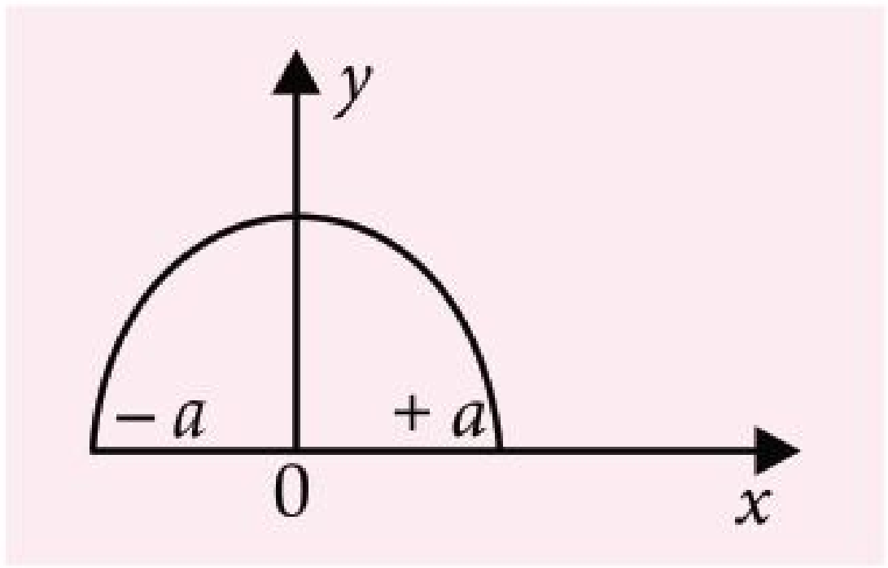
C. $B = \frac{\mu_0 I}{\pi^2 R}$ D. $B = \frac{\mu_0 I}{2R}$

8. Calculate the self inductance per unit length of a current loop formed by joining the ends of two long parallel wires of radius r separated by a distance d between their axes, neglecting the end effects and magnetic flux within the wires.

A. $\frac{\mu_0}{\pi}\log_e \frac{d-r}{r}$ B. $\frac{\mu_0}{2\pi}\log_e \frac{d-r}{r}$

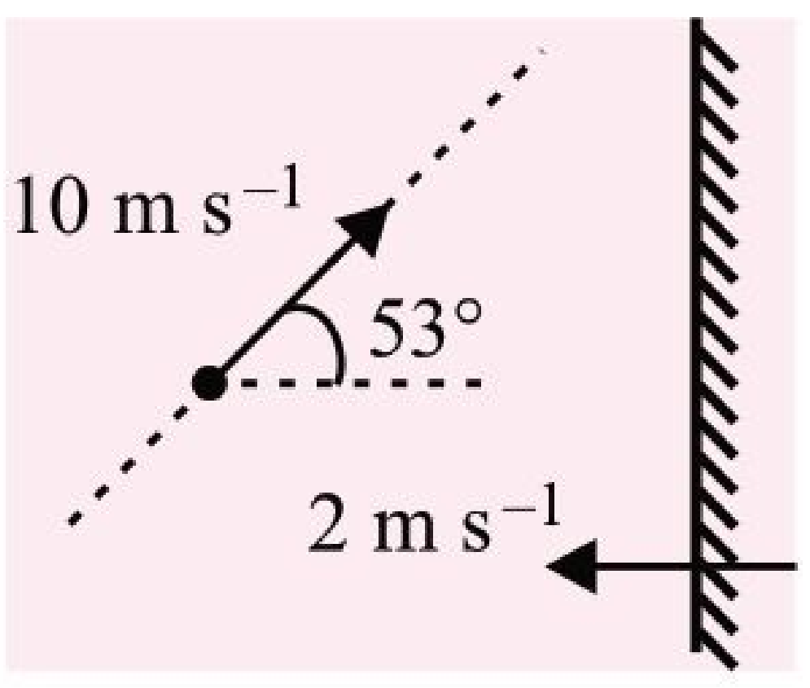
C. $\frac{\mu_0}{\pi}\log_e \frac{r}{d-r}$ D. $\frac{\mu_0}{2\pi}\log_e \frac{r}{d-r}$

9. Determine the rms value of a semi-circular current wave which has a maximum value of a.



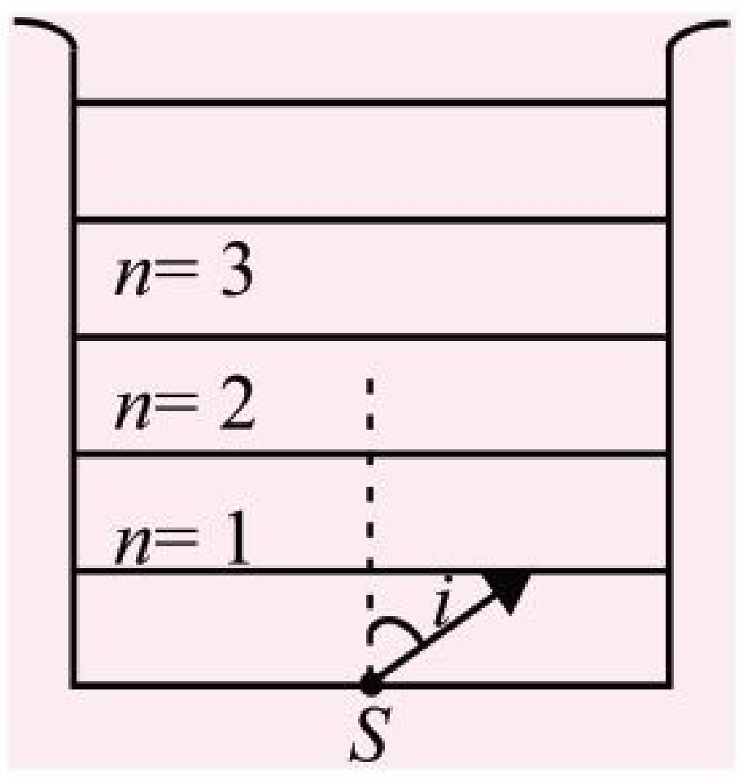
A. $(1/\sqrt{2})a$
B. $\sqrt{(3/2)}a$
C. $\sqrt{(2/3)}a$
D. $(1/\sqrt{3})a$

10. Find the speed of image of a moving particle shown in figure.



A. $\sqrt{204}$ m s^{-1}
B. 17 m s^{-1}
C. $\sqrt{164}$ m s^{-1}
D. 13 m s^{-1}

11. A point source S is placed at the bottom of different layers as shown in the figure. The refractive index of bottom most layer is μ_0. The refractive index of any other upper layer is $\mu(n) = \mu_0 + \frac{\mu_0}{4n-18}$. A ray of light with angle i = 30° starts from the source S. Total internal reflection takes place at the upper surface of layer having n equal to



A. 3 B. 5 C. 4 D. 6

12. A ray of light passes through a prism in a principal plane, the deviation being equal to angle of incidence which is equal to 2α. It is given that α is

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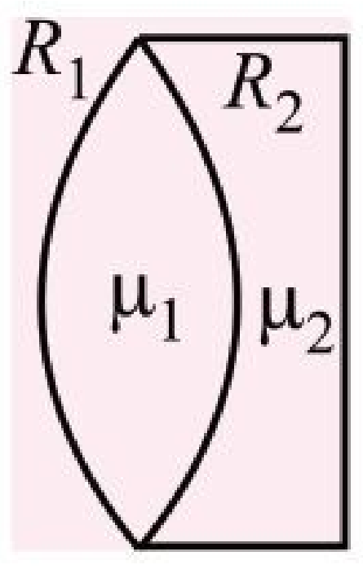
the angle of prism and μ is the refractive index of the material of prism, then

A. $\cos\alpha = \sqrt{\frac{\mu^2-1}{2}}$ B. $\cos\alpha = \sqrt{\frac{\mu^2-1}{8}}$

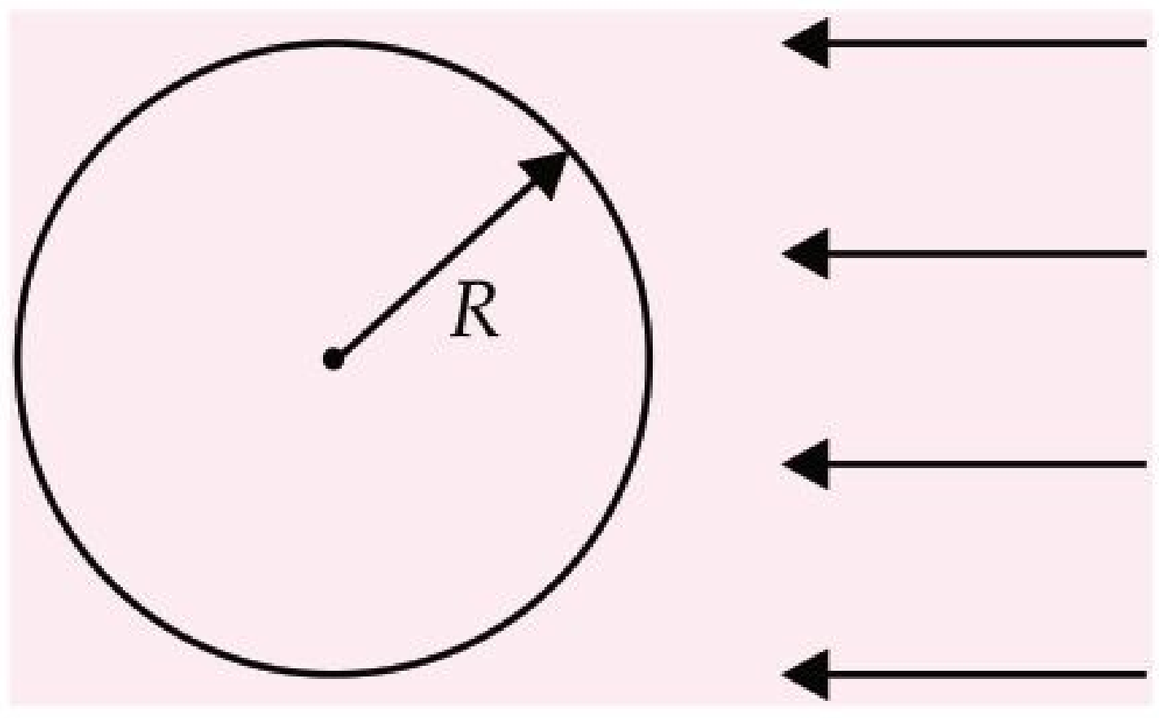
C. $\sin\alpha = \sqrt{\mu^2-1}$ D. $\sin\alpha\sqrt{\frac{\mu^2-1}{8}}$

13. Find focal length of the combination of a biconvex and a plano-concave lens kept in contact with plane surface silvered $\mu_1 = \frac{4}{3}, \mu_2 = \frac{3}{2}$, $R_1 = 20$ cm and $R_2 = 30$ cm.



A. −45 cm B. +15 cm C. +45 cm D. −15 cm

14. A plane wave of intensity $I = 0.70$ W cm^{-2} illuminates a sphere with ideal mirror surface. The radius of sphere is $R = 5.0$ cm. From the standpoint of photon theory, find the force that light exerts on the sphere.



A. 0.183 μN B. 0.2 μN

C. 0.5 μN D. 1.2 μN

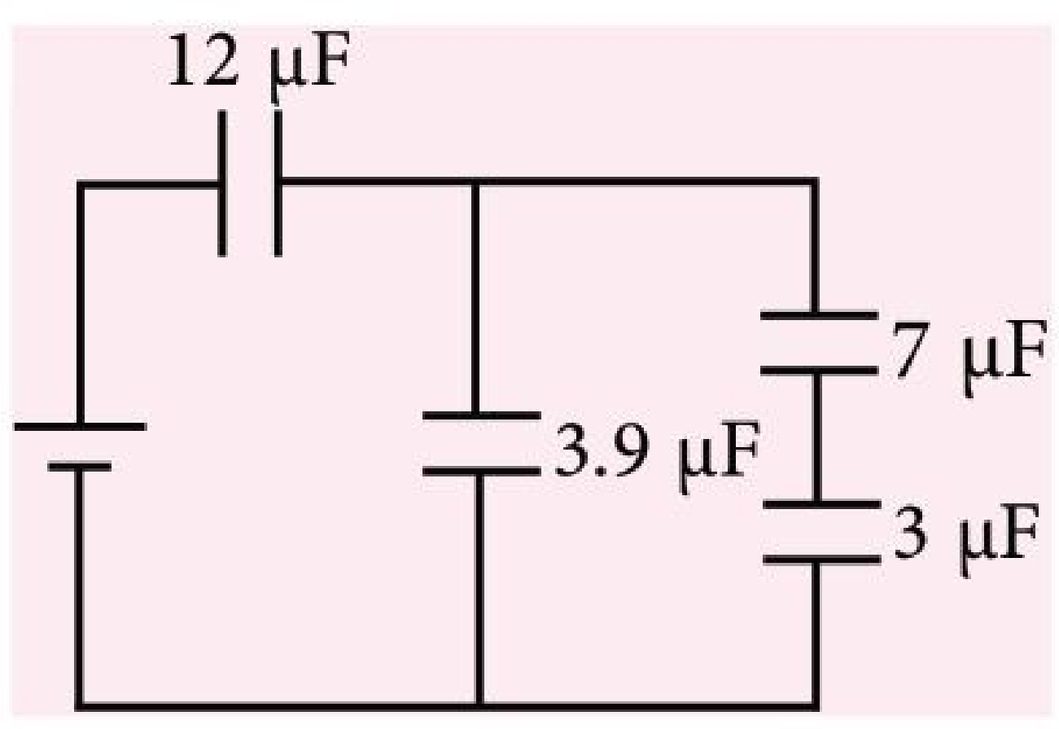
15. A radioactive material of half-life T was produced in a nuclear reactor at different instants. The quantity produced second time was twice of that produced first time. If now their present activities are A_1 and A_2 respectively then their age difference equals

A. $\frac{T}{\ln 2}\left|\ln\frac{2A_1}{A_2}\right|$ B. $T\left|\ln\frac{A_1}{A_2}\right|$

C. $\frac{T}{\ln 2}\left|\ln\frac{A_2}{2A_1}\right|$ D. $T\left|\ln\frac{A_2}{2A_1}\right|$

ACHIEVERS SECTION

16. Four capacitors and a battery are connected as shown in the figure. If the potential difference across the 7 μF capacitor is 6 V, then which of the following statements are correct?



I. The potential drop across the 12 μF capacitor is 10 V.

II. The charge in the 3 μF capacitor is 42 μC.

III. The potential drop across the 3 μF capacitor is 10 V.

IV. The emf of the battery is 30 V.

A. I and II only B. III and IV only

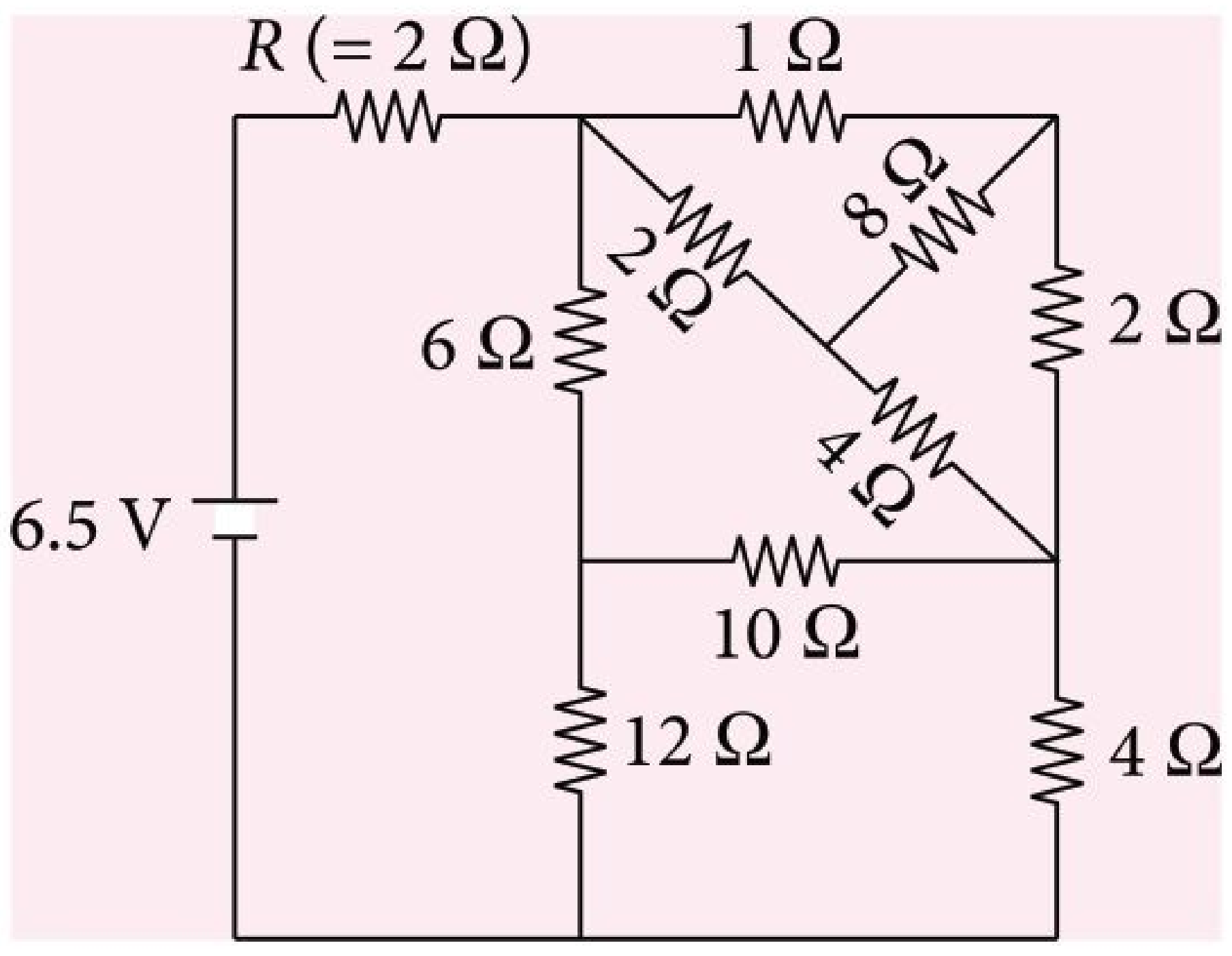
C. II, III and IV only D. I, II and IV only

17. A nucleus of mass 20 u emits a γ photon of energy 6 MeV. If the emission assume to occur when nucleus is free and at rest, then the nucleus will have kinetic energy nearest to (Take 1 u = 1.6×10^{-27} kg)

A. 10 keV B. 1 keV

C. 0.1 keV D. 100 keV

18. In the following circuit, the current through the resistor R (= 2 Ω) is I amperes. The value of I is



A. 1 B. 5 C. 6 D. 4

Direction (Q.No 19 and 20) : Read the given passage and answer the following questions.

In a photoelectric setup, a point source of light of power 3.2×10^{-3} W emits photons of energy 5.0 eV. The source is located at a distance of 0.8 m from the centre of a stationary metallic sphere of work function 3.0 eV and of radius 8.0×10^{-3} m. The efficiency of photoelectron emission is 1 for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral and photoelectrons are instantaneously swept away after emission.

19. Find the number of photoelectrons emitted per second.

A. 10^3 B. 10^4 C. 5×10^4 D. 10^5

20. It is observed that photoelectron emission stops at a certain time t after the light source is switched on. It is due to the retarding potential developed in the metallic sphere due to left over positive charges. Find t.

A. 1.85 minutes B. 2.36 minutes

C. 2.75 minutes D. 0.78 minutes

Darken your choice with HB Pencil

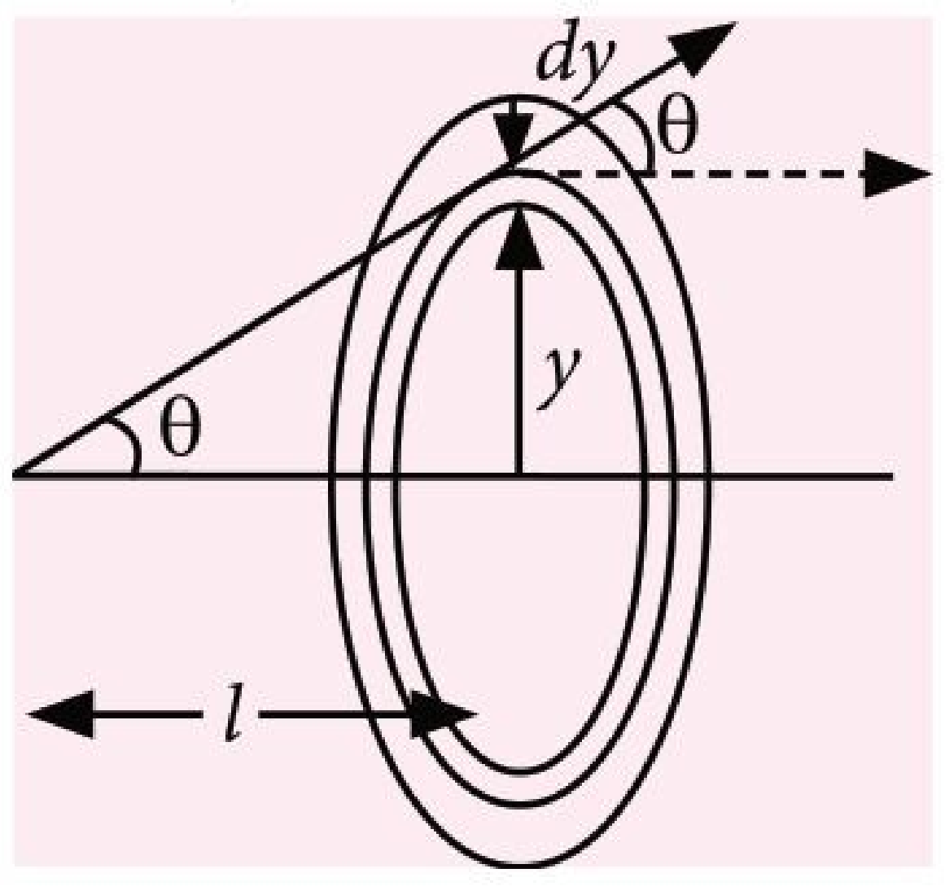
1.	Ⓐ Ⓑ Ⓒ Ⓓ	**5.**	Ⓐ Ⓑ Ⓒ Ⓓ	**9.**	Ⓐ Ⓑ Ⓒ Ⓓ	**13.**	Ⓐ Ⓑ Ⓒ Ⓓ	**17.**	Ⓐ Ⓑ Ⓒ Ⓓ
2.	Ⓐ Ⓑ Ⓒ Ⓓ	**6.**	Ⓐ Ⓑ Ⓒ Ⓓ	**10.**	Ⓐ Ⓑ Ⓒ Ⓓ	**14.**	Ⓐ Ⓑ Ⓒ Ⓓ	**18.**	Ⓐ Ⓑ Ⓒ Ⓓ
3.	Ⓐ Ⓑ Ⓒ Ⓓ	**7.**	Ⓐ Ⓑ Ⓒ Ⓓ	**11.**	Ⓐ Ⓑ Ⓒ Ⓓ	**15.**	Ⓐ Ⓑ Ⓒ Ⓓ	**19.**	Ⓐ Ⓑ Ⓒ Ⓓ
4.	Ⓐ Ⓑ Ⓒ Ⓓ	**8.**	Ⓐ Ⓑ Ⓒ Ⓓ	**12.**	Ⓐ Ⓑ Ⓒ Ⓓ	**16.**	Ⓐ Ⓑ Ⓒ Ⓓ	**20.**	Ⓐ Ⓑ Ⓒ Ⓓ

SOLUTIONS

1. (A) : Electric field at distance y on the circle due to both charges is

$$E = 2\times\frac{kq}{(l^2+y^2)}\times\cos\theta = \frac{2kq}{l^2+y^2}\times\frac{l}{\sqrt{l^2+y^2}}$$

$$E = \frac{2kql}{[l^2+y^2]^{3/2}}$$ (Along the dotted line)



Flux through the width dy of circle

$d\phi = E\,(2\pi y.\,dy)$ (Angle = 0°)

$$\int d\phi = 2\pi(2kql)\int_0^R \frac{y\,dy}{[l^2+y^2]^{3/2}}$$

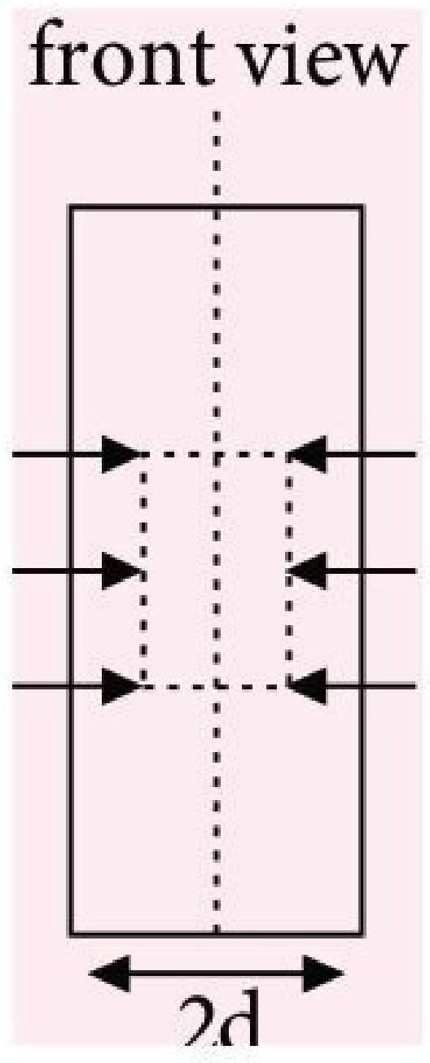
Let $l^2 + y^2 = x$

$\therefore\ 2ydy = dx$ and putting $k = 1/4\pi\in_0$

$$\phi = \frac{ql}{\in_0}\int_{l^2}^{l^2+R^2}\frac{dx}{2(x)^{3/2}} = \frac{ql}{2\in_0}\cdot\left[\frac{x^{\frac{-3}{2}+1}}{\frac{-3}{2}+1}\right]_{l^2}^{l^2+R^2}$$

$$= -\frac{ql}{\varepsilon_0}\left[\frac{1}{\sqrt{R^2+l^2}}-\frac{1}{l}\right] = \frac{q}{\varepsilon_0}\left[1-\frac{l}{\sqrt{l^2+R^2}}\right]$$

2. (A) : If we draw a cuboid Gaussian surface of lateral cross-section A and height h and width $2x$ where x = distance from central line, then E will be pointing as shown in figure (by symmetry).



$$\phi_g = \int \vec{E}\cdot d\vec{s} = 2EA = \frac{q_{\text{enclosed}}}{\varepsilon_0}$$

(Flux through lateral surface,
if E = Electric field at distance x)

$q_{\text{enclosed}} = [(l)(2x)(h)]\rho$

$$2EA = \frac{q_{\text{enclosed}}}{\varepsilon_0} = \frac{(2x)(l)h\rho}{\varepsilon_0} = \frac{2xA\rho}{\varepsilon_0}\ \left[\text{as } lh = A\right]$$

So, $E = -\dfrac{\rho}{\varepsilon_0}x$. Force $= -qE = -\dfrac{q\rho}{\varepsilon_0}x$

or $m\dfrac{d^2x}{dt^2} = \dfrac{-q\rho}{\varepsilon_0}x \Rightarrow \omega^2 = \dfrac{q\rho}{\varepsilon_0 m}$

$$\omega = \sqrt{\frac{q\rho}{\varepsilon_0 m}} \quad\Rightarrow\quad \upsilon = \frac{1}{2\pi}\sqrt{\frac{q\rho}{m\varepsilon_0}}$$

3. (C) : $dC_1 = \dfrac{K_1\varepsilon_0 a dx}{d - x\tan\theta};\ dC_2 = \dfrac{K_2\varepsilon_0 a dx}{x\tan\theta}$

dC_1 and dC_2 are in series

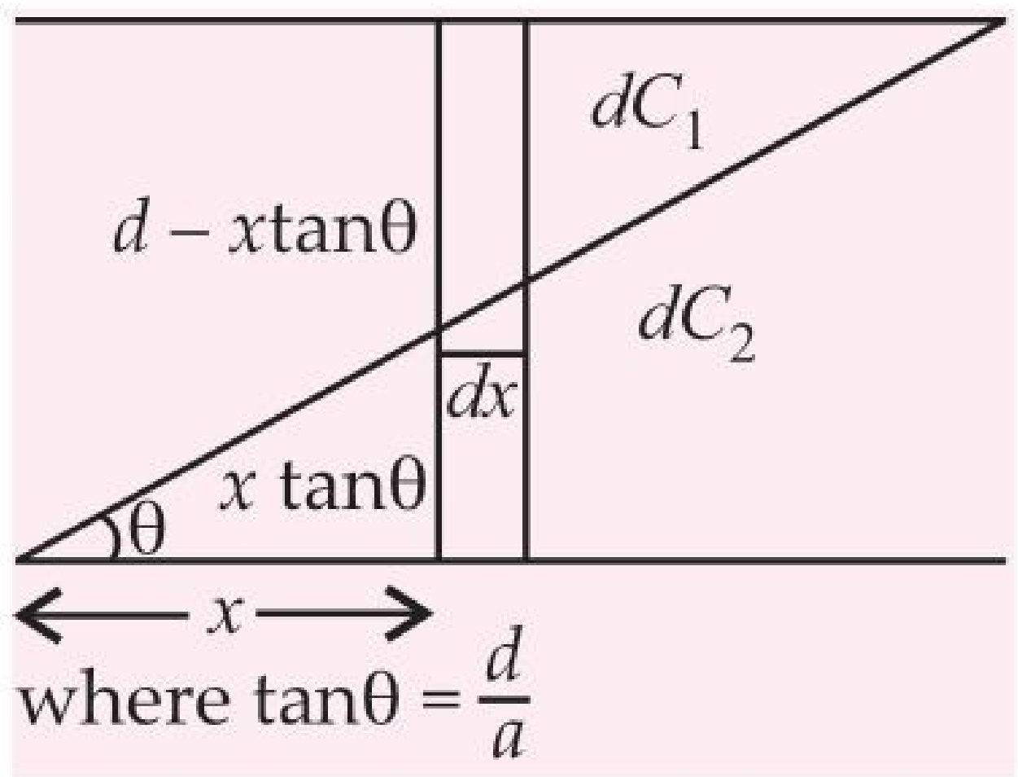
$\therefore$ Its equivalent dC will be given by, $\dfrac{1}{dC} = \dfrac{1}{dC_1} + \dfrac{1}{dC_2}$

$$= \frac{d-x\tan\theta}{K_1\varepsilon_0 adx} + \frac{x\tan\theta}{K_2\varepsilon_0 adx} = \frac{1}{\varepsilon_0 adx}\left(\frac{d-x\tan\theta}{K_1}+\frac{x\tan\theta}{K_2}\right)$$

$$\frac{1}{dC} = \frac{1}{K_1K_2\varepsilon_0 adx}[K_2(d-x\tan\theta)+K_1(x\tan\theta)]$$

$$= \frac{1}{K_1K_2\varepsilon_0 adx}[K_2d + x\tan\theta(K_1-K_2)]$$

$$\therefore\ dC = \frac{K_1K_2\varepsilon_0 adx}{K_2d + x\tan\theta(K_1-K_2)}$$



The elementary capacitor dC is placed in parallel to form the original capacitor.

$$\int dC = K_1K_2\varepsilon_0 a\int_0^a \frac{dx}{K_2d + x\tan\theta(K_1-K_2)}$$

$$C = \frac{K_1K_2\varepsilon_0 a}{\tan\theta(K_1-K_2)}\Big|\ln[K_2d + x\tan\theta(K_1-K_2)]\Big|_0^a$$

$$= \frac{K_1K_2\varepsilon_0 a}{\tan\theta(K_1-K_2)}\ln\left(\frac{K_2d + a\tan\theta(K_1-K_2)}{K_2d}\right)$$

Putting the value of $\tan\theta = \dfrac{d}{a}$, we get

$$C = \frac{K_1K_2\varepsilon_0 a^2}{d(K_1-K_2)}\ln\frac{K_1}{K_2}$$

4. (B) : Equation of potential as a function of time during charging of a capacitor,

$$V = V_0\left(1 - e^{-t/R_{eq}C_{eq}}\right)$$

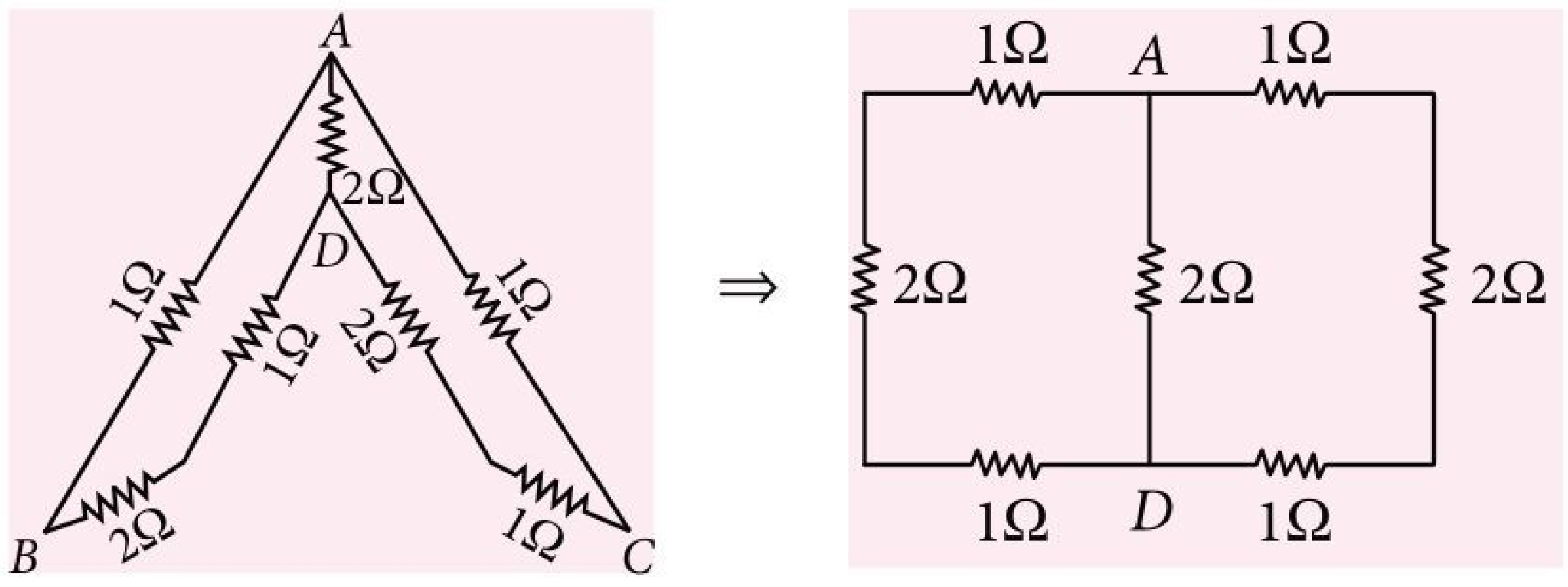
$C_{eq} = 2 + 2 = 4\ \mu$F and $R_{eq} = 1$ MΩ

$$\therefore\ 4 = 10\left(1-e^{-\frac{t}{10^6\times4\times10^{-6}}}\right) \Rightarrow e^{-t/4} = 0.6$$

$$\Rightarrow\ e^{t/4} = \frac{5}{3} \quad\Rightarrow\quad \frac{t}{4} = \ln 5 - \ln 3 \quad\Rightarrow\quad t = 0.5\times4$$

$t = 2$ s

5. (C) : By the symmetry of paths, points E, F and B, C are equipotential.



$$\therefore\quad \frac{1}{R_{AD}} = \frac{1}{2} + \frac{1}{1+2+1} + \frac{1}{1+2+1} \ \Rightarrow\ R_{AD} = 1\Omega$$

6. (B) : When S_2 open at $l = L/2$:

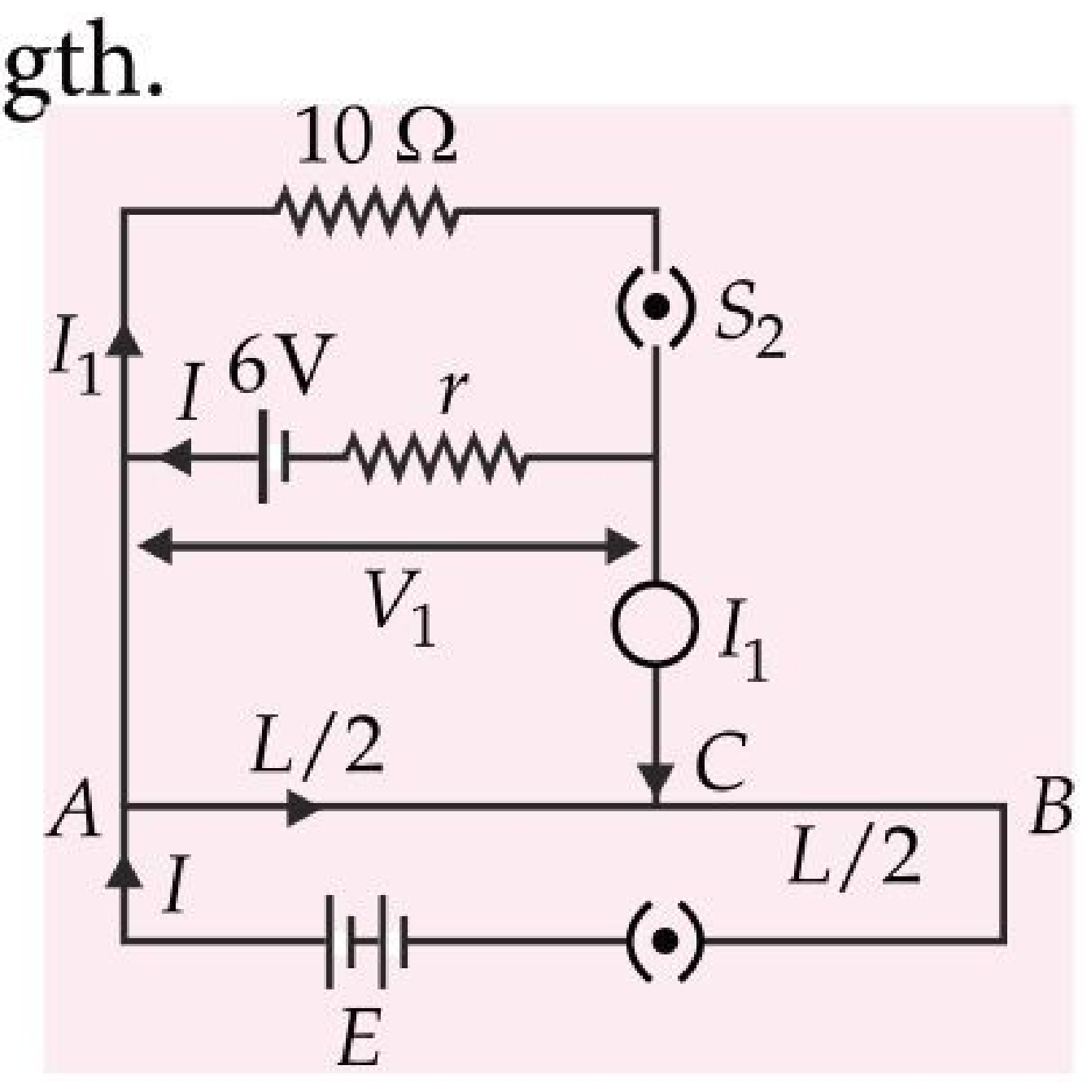
Assume resistance of $AB = R$

Resistance of wire per unit length.

$x = R/L$

$i = E/R$

Now in path AC,



$$\frac{E}{R}\times\frac{R}{L}\times\frac{L}{2} = 6$$

$E = 12$ V

When S_2 closed at $5L/12$:

$$V_1 = \frac{E}{R}\times\frac{R}{L}\times\frac{5L}{12} = \frac{5E}{12} = \frac{5\times12}{12} = 5\text{ V} \quad\Rightarrow 6 - I_1r = 5$$

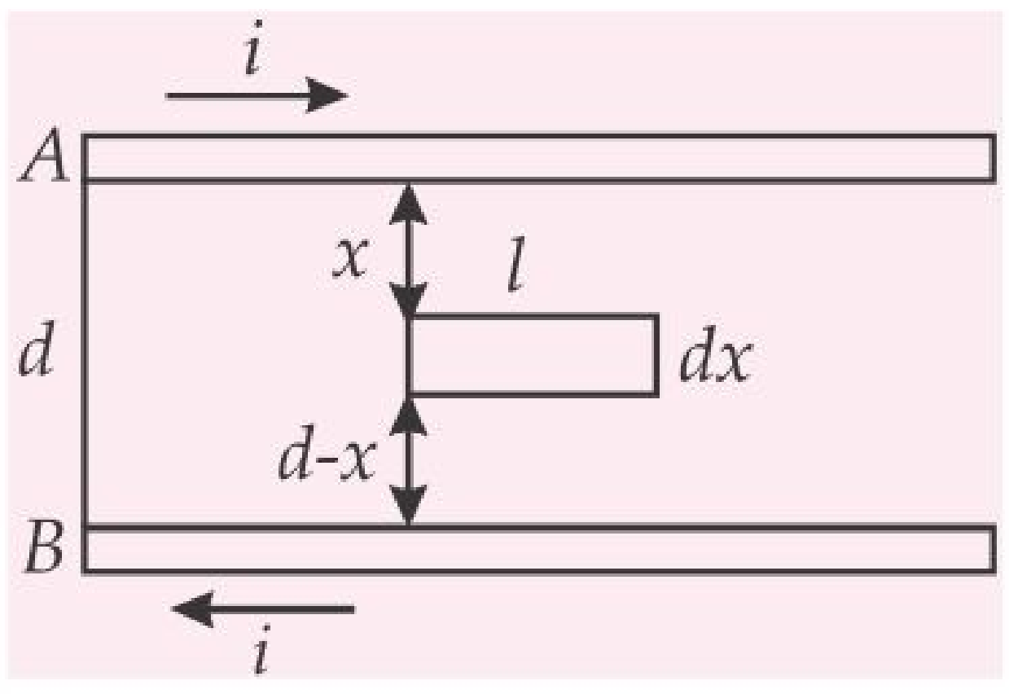
$$\Rightarrow\quad 6-\left(\frac{5}{10}\right)r = 5 \quad\Rightarrow r = 2\ \Omega$$

7. (C)

8. (A) : Let A and B are the two long parallel wires as shown which are joined to form a current loop. The two wires would obviously be carrying equal currents in opposite direction.

Consider a space length l and thickness dx as shown in figure.

The magnetic flux through the area l/dx due to the currents in the two wires is $d\phi = Bldx$ where B is the intensity of magnetic field due to current carrying wires at a distance x from A.



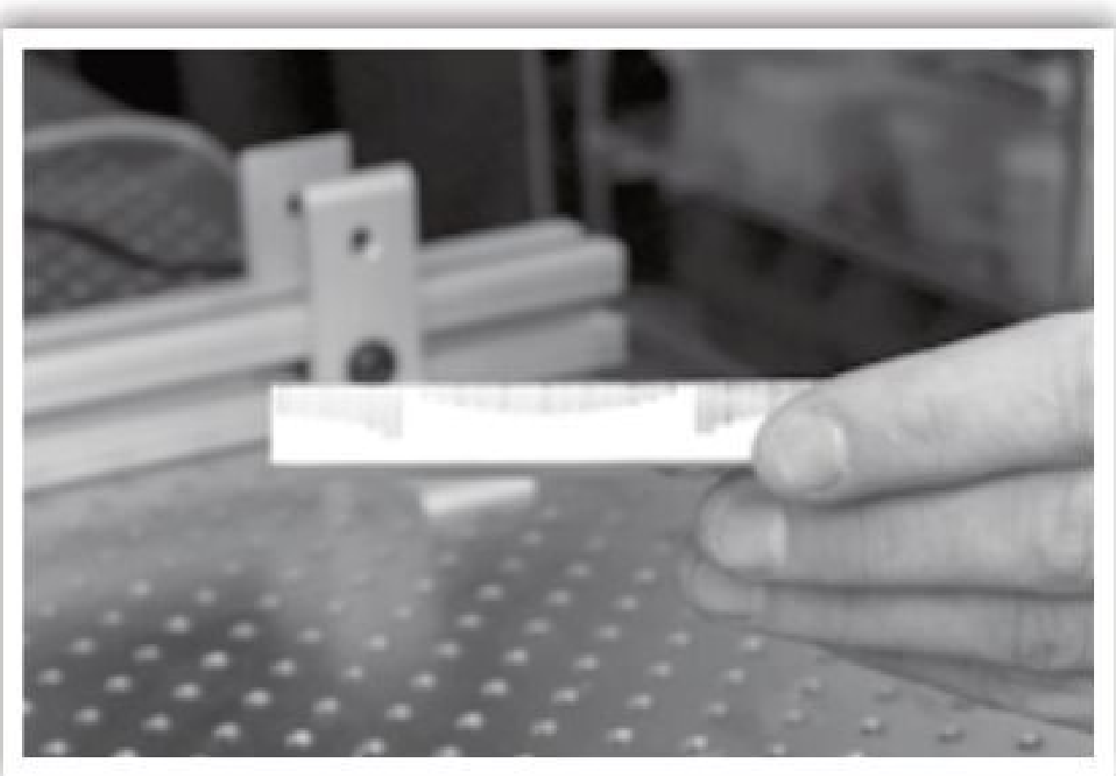
$$B = \frac{\mu_0}{4\pi}\frac{2i}{x} + \frac{\mu_0}{4\pi}.\frac{2i}{d-x}$$

$$d\phi = Bldx = \frac{\mu_0 i}{2\pi}\left(\frac{1}{x}+\frac{1}{d-x}\right)ldx$$

Physics bulletin

Using ultrasound waves, scientists are able to move objects hands-free!!

Telekinesis, or the ability to control things around us with our minds is a superpower, we all wish we possessed. This science fiction could soon become a reality as researchers from the University of Minnesota have devised a new method for moving objects hands-free using ultrasound waves.



The study is published in Nature Communications, which is an open-access scientific journal.

The University of Minnesota team has developed a method that can move larger objects using the principles of metamaterial physics.

Metamaterials are materials that are artificially engineered to interact with waves, like light and sound. By placing a metamaterial pattern on the surface of an object, the researchers were able to use sound to steer it in a certain direction without physically touching it.

Ognjen Ilic, senior author of the study and **the Benjamin Mayhugh** Assistant Professor in the University of Minnesota, Department of Mechanical Engineering, said "We have known for a while that waves and light and sound can manipulate objects. What sets our research apart is that we can manipulate and trap much bigger objects if we make their surface a metamaterial surface, or a 'metasurface,'' He further added, "When we place these tiny patterns on the surface of the objects, we can basically reflect the sound in any direction we want. And in doing that, we can control the acoustic force that is exerted on an object."

Such contactless manipulation method could be used in a lot of fields of science and engineering, especially, robotics. There is the need to move things, to transfer a signal into some sort of controlled motion. Often this is done through physical tethers or having to carry some source of energy to be able to perform a task. By using this latest technology without physical contact, objects could be moved and that motion can be controlled simply by programming, what is on the surface of that object. This could give a new mechanism to contactless actuate things.

$$\phi = \int_{r}^{d-r} \frac{\mu_0 i}{2\pi}\left(\frac{1}{x}+\frac{1}{d-x}\right) l dx$$

$$= \frac{\mu_0 il}{2\pi}[\log_e x - \log_e (d-x)]_r^{d-r} = \frac{\mu_0 il}{\pi}\log_e \frac{d-r}{r}$$

Magnetic flux linked with unit length of the loop $= \frac{\mu_0 i}{\pi}\log_e \frac{d-r}{r}$

But $\phi = Li$ where L is self-inductance.

$$\therefore \quad L = \frac{\mu_0}{\pi}\log_e \frac{d-r}{r}$$

9. (C) : The equation of a semi-circular wave is $x^2 + y^2 = a^2$ or $y^2 = a^2 - x^2$

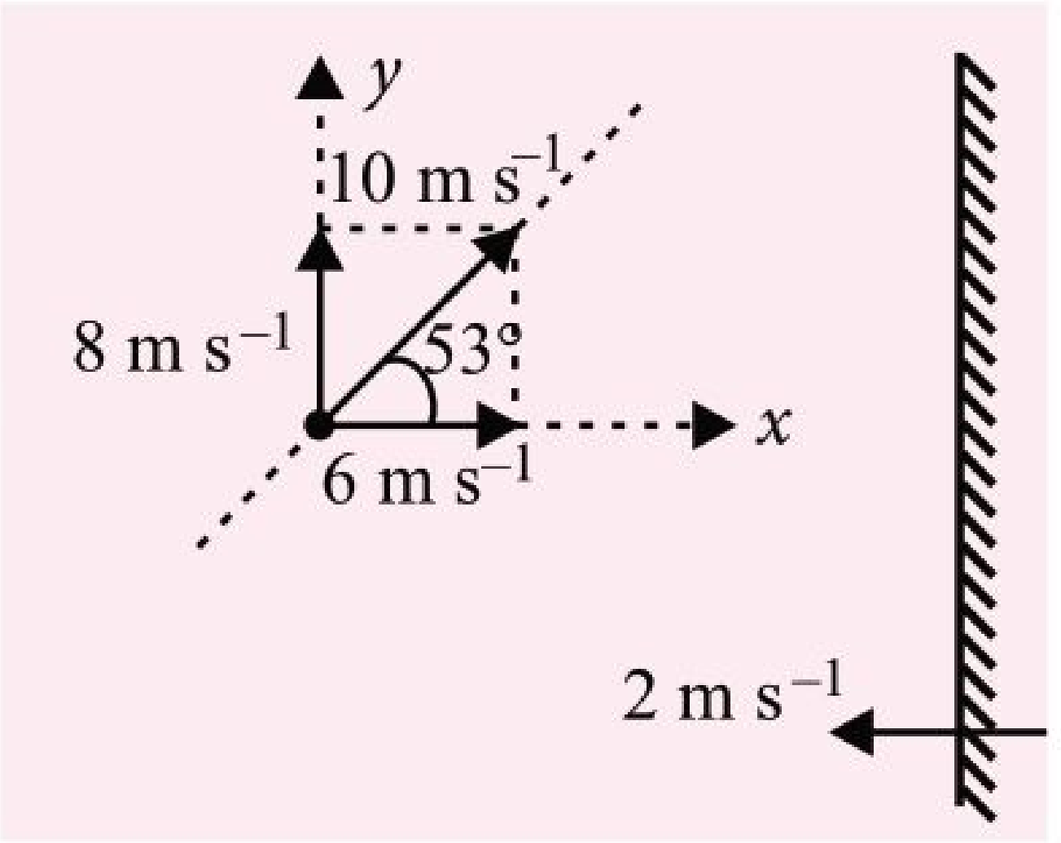
$$I_{\text{rms}} = \sqrt{\frac{1}{2a}\int_{-a}^{+a} y^2 dx}\ ;\ I^2_{\text{rms}} = \frac{1}{2a}\int_{-a}^{+a}(a^2 - x^2)dx$$

$$= \frac{1}{2a}\int_{-a}^{+a}(a^2 - x^2)dx = \frac{1}{2a}\left|a^2 x - \frac{x^3}{3}\right|_{-a}^{+a}$$

$$= \frac{1}{2a}\left(a^3 - \frac{a^3}{3} + a^3 - \frac{a^3}{3}\right) = \frac{2a^2}{3}$$

$$I_{\text{rms}} = \sqrt{\frac{2a^2}{3}} = \sqrt{\frac{2}{3}}a$$

10. (C) : The component of velocity of image perpendicular to mirror is



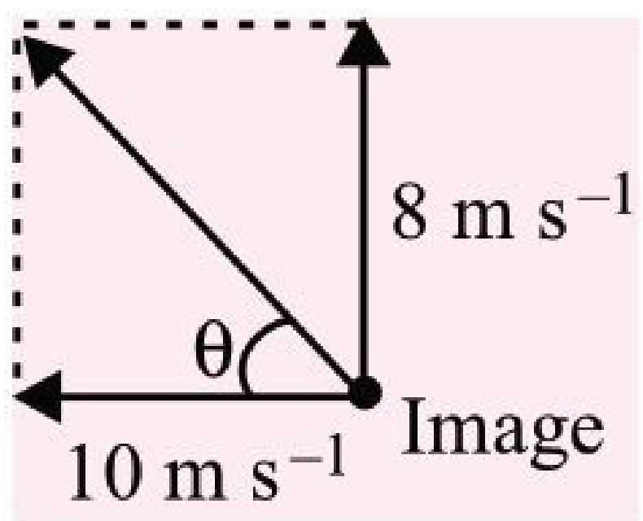
$$\vec{v}_I = 2\vec{v}_M - \vec{v}_0$$

$$(v_I)_\perp = 2(-2) - (6) = -10 \text{ m s}^{-1}$$

For the component of velocity of image parallel to the mirror,

$$(\vec{v}_1)_{||} = 8 \text{ m s}^{-1}$$

$\therefore$ Velocity of image (v_I)



$$= \sqrt{(v_I)_\perp^2 + (v_I)_{||}^2}$$

$$\Rightarrow \quad v_I = \sqrt{100+64} = \sqrt{164} \text{ m s}^{-1}$$

11. (C) : For parallel composite slab,

$u\sin\theta$ = constant

$\mu_0 \times \sin i = \mu(n) \times \sin 90°$

$$\mu_0 \sin 30° = \mu_0 + \frac{\mu_0}{4n-18}$$

$$\frac{1}{2} = 1 + \frac{1}{4n-18} \Rightarrow \frac{1}{18-4n} = \frac{1}{2} \Rightarrow n = 4$$

$\therefore$ Total internal reflection takes place at the upper surface of layer having $n = 4$.

12. (B) : $2\alpha = (2\alpha + e) - \alpha \quad \therefore e = \alpha$ and $r_1 + r_2 = \alpha$

$\sin 2\alpha = \mu\sin(r_1)$, $\mu\sin(\alpha - r_1) = \sin\alpha$

$\mu(\sin\alpha \,.\, \cos r_1 - \cos\alpha \sin r_1) = \sin\alpha$

$$\mu\left[\sin\alpha\sqrt{1 - \frac{\sin^2 2\alpha}{\mu^2}} - \frac{\cos\alpha \sin 2\alpha}{\mu}\right] = \sin\alpha$$

$$\sin\alpha\sqrt{\mu^2 - \sin^2 2\alpha} - \cos\alpha\sin 2\alpha = \sin\alpha$$

$$\sqrt{\mu^2 - \sin^2 2\alpha} - 2\cos^2\alpha = 1$$

$\mu^2 - \sin^2 2\alpha = 1 + 4\cos^4\alpha + 4\cos^2\alpha$

$\mu^2 = 1 + 4\cos^4\alpha + 4\cos^2\alpha + 4\sin^2\alpha\cos^2\alpha$

$\mu^2 = 1 + 4\cos^2\alpha(\sin^2\alpha + \cos^2\alpha)$

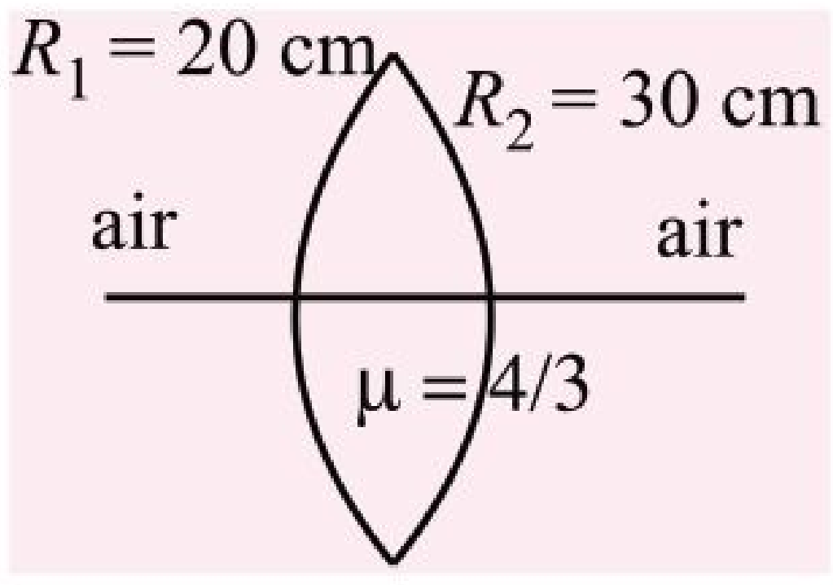
$$\therefore \ \cos\alpha = \sqrt{\frac{\mu^2 - 1}{8}}$$

13. (A) : Equivalent focal length is given by

$$-\frac{1}{F} = \frac{2}{f_{l_1}} + \frac{2}{f_{l_2}} + \left(-\frac{1}{f_m}\right) \quad \text{...(i)}$$

where F is the focal length of the equivalent mirror.

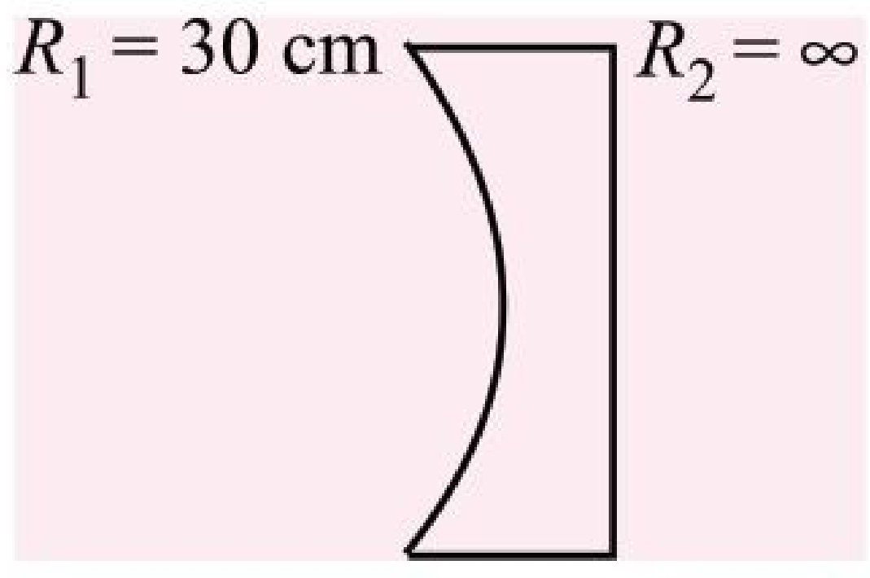
For first lens in air



$$\frac{1}{f_{l_1}} = \left(\frac{4/3}{1} - 1\right)\left(\frac{1}{20} - \frac{1}{-30}\right)$$

or $f_{l_1} = 36$ cm

For second lens in air



$$\frac{1}{f_{l_2}} = \left(\frac{\frac{3}{2}}{1} - 1\right)\left(\frac{1}{-30} - \frac{1}{\infty}\right)$$

or $f_{l_2} = -60$ cm

For mirror, $f_m = \frac{R}{2} = \infty$

Putting the values in eq. (i),

$$-\frac{1}{F} = \frac{2}{36} + \frac{2}{-60} + \left(-\frac{1}{\infty}\right) \quad \Rightarrow F = -45 \text{ cm}$$

14. (A)

15. (C) : $A_1 = \lambda N_0 e^{-\lambda t_1}$ or $t_1 = \frac{1}{\lambda}\ln\left(\frac{\lambda N_0}{A_1}\right)$ ...(i)

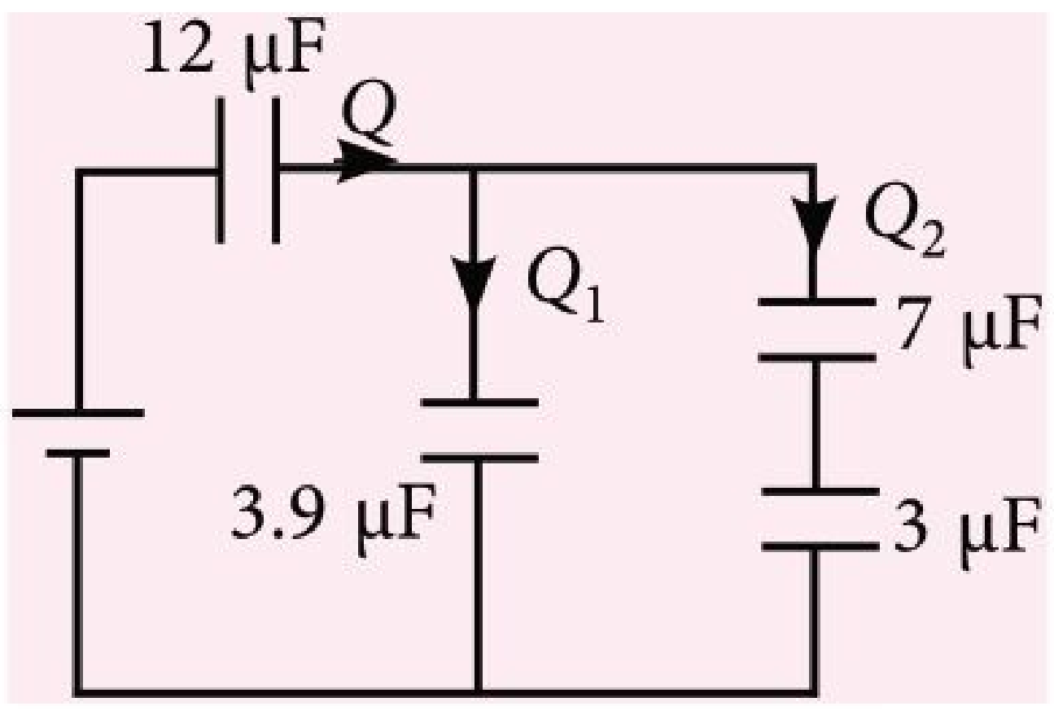
$A_2 = (\lambda)(2N_0)e^{-\lambda t2}$

$$\therefore \ t_2 = \frac{1}{\lambda}\ln\left(\frac{2\lambda N_0}{A_2}\right) \quad \text{...(ii)}$$

From eqns. (i) and (ii),

$$t_1 - t_2 = \frac{1}{\lambda}\ln\left(\frac{A_2}{2A_1}\right) = \frac{T}{\ln(2)}\ln\left(\frac{A_2}{2A_1}\right)$$

16. (D) : 7 μF and 3 μF are in series.



$$\therefore\ C_s = \frac{7\times3}{7+3} = 2.1\,\mu\text{F}$$

Now C_s and 3.9 μF are in parallel.

So, $C_p = 3.9 + 2.1 = 6\ \mu\text{F}$

$$\text{So, } C_{eq} = \frac{12\times6}{12+6} = 4\,\mu\text{F}$$

Total charge, $Q = C_{eq}V = 4V\ \mu\text{C}$

Charge on 7 μF or 3 μF is $Q_2 = 7\times6 = 42\ \mu\text{C}$

$$\text{So, } \frac{Q_2}{2.1\,\mu\text{F}} = \frac{Q_1}{3.9\mu\text{F}} \Rightarrow Q_1 = 42\times\frac{3.9}{2.1} = 78\,\mu\text{C}.$$

$$Q = Q_1 + Q_2 = 78\,\mu\text{C} + 42\,\mu\text{C} = 120\,\mu\text{C}$$

or $4V$ μC = 120 μC $\therefore$ $V = 30$ V

Potential difference across 12 μF $= \frac{120}{12} = 10$ V.

17. (B) : Given that, energy, $E = 6\text{ MeV} = 6\times1.6\times10^{-13}$ J

$m = 20\text{ u} = 20\times1.6\times10^{-27}$ kg

Momentum of γ-photon, $p = E/c$

By conservation of momentum, momentum of nucleus is equal to the momentum of the γ-photon.

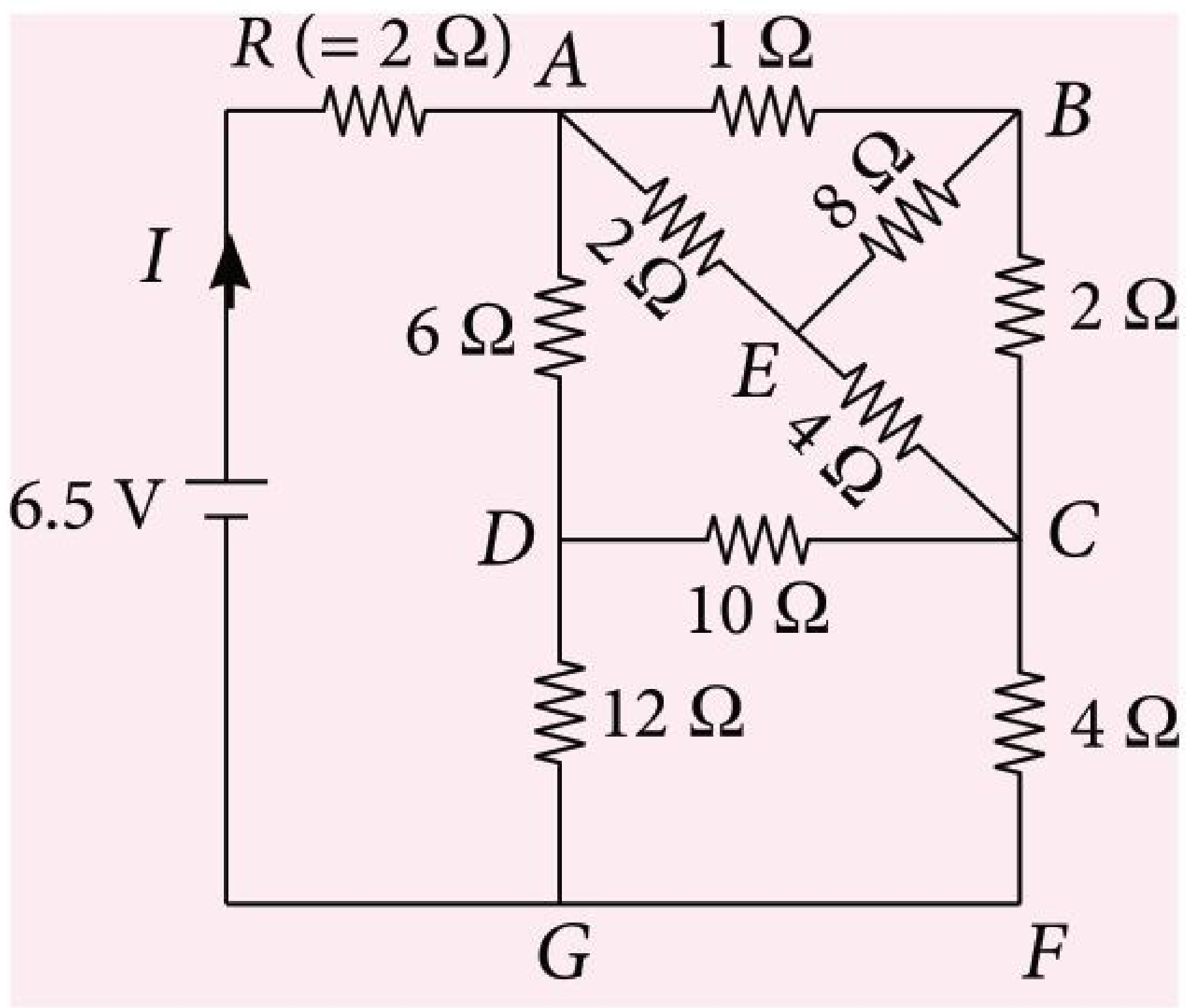
$\therefore$ Momentum of nucleus, $P = p = E/c$

$$\text{Now } KE \text{ of nucleus, } K = \frac{P^2}{2\,m} = \frac{E^2}{2mc^2}$$

$$\therefore\ K = \frac{(6\times1.6\times10^{-13})^2}{2\times(20\times1.6\times10^{-27})\times(3\times10^8)^2} = 1.6\times10^{-16}\text{ J}$$

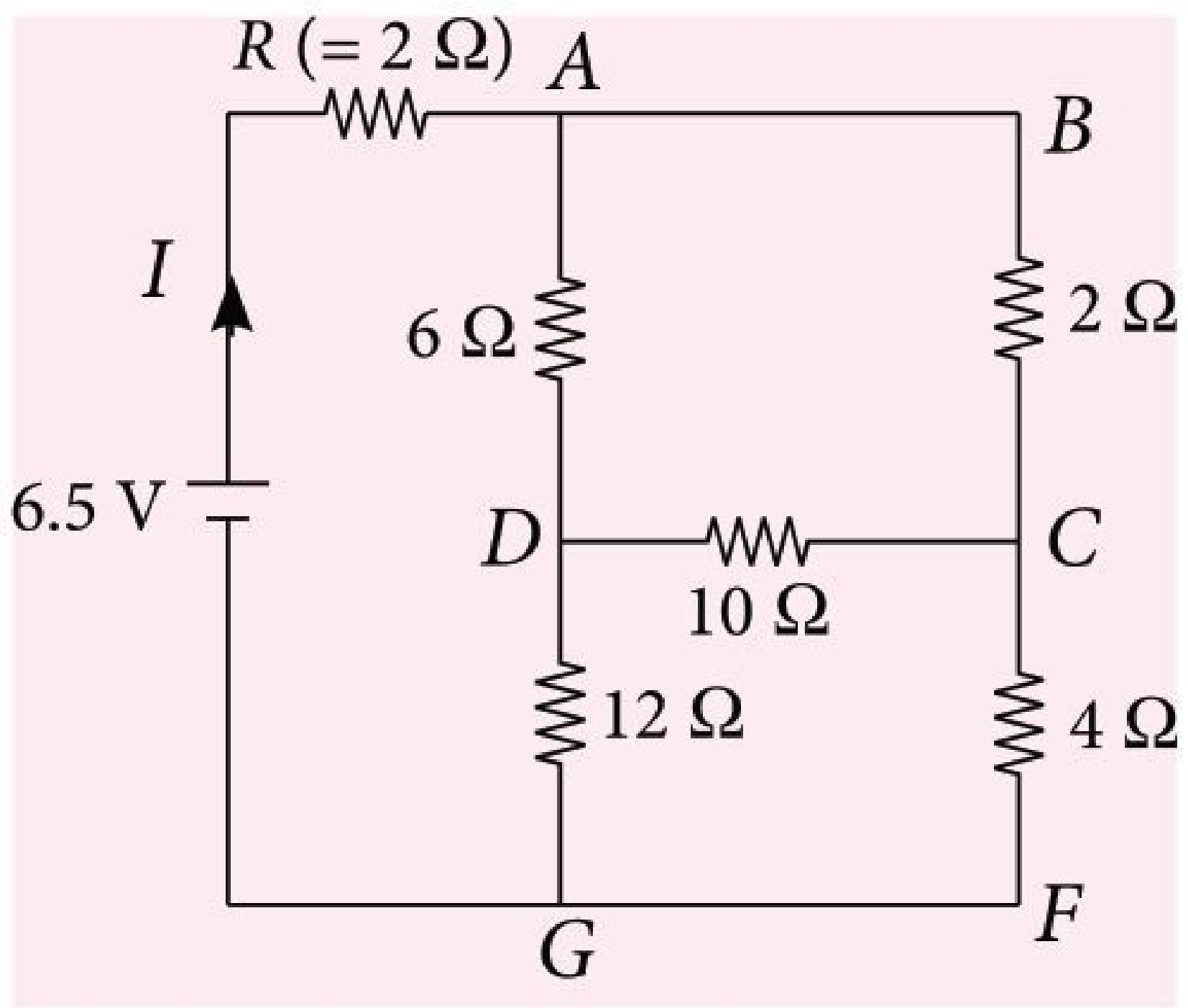
$$\text{or } K = \frac{1.6\times10^{-16}}{1.6\times10^{-19}}\text{ eV} = 1000\text{ eV} = 1\text{ keV}$$

18. (A) : *ABCEA* is a balanced wheatstone bridge.



$$\therefore\ R_{eq} = \frac{(1+2)(2+4)}{(1+2)+(2+4)} = \frac{18}{9} = 2\,\Omega$$

Now, *ABCFGDA* is a balanced wheatstone bridge.



$$R_{AG} = \frac{6\times18}{6+18} = \frac{108}{24} = 4.5\,\Omega$$

$$R_{\text{total}} = 2 + 4.5 = 6.5\,\Omega$$

$$\therefore\ i = \frac{V}{R_{\text{total}}} = \frac{6.5}{6.5} = 1\text{ A}$$

19. (D) : Energy of emitted photons

$E_1 = 5.0\text{ eV} = 5.0\times1.6\times10^{-19} = 8\times10^{-19}$ J

Energy emitted per second by the source

$E_2 = 3.2\times10^{-3}$ J

Number of photons emitted per second $= \frac{E_2}{E_1} = 4\times10^{15}$

Number of photons incident on the sphere per sec,

$$n = \frac{4\times10^{15}}{4\pi(0.8)^2}\times\pi(8\times10^{-3})^2 = 10^{11}$$

Number of photoelectrons emitted per second,

$$n' = \frac{10^{11}}{10^6} = 10^5 \text{ per second.}$$

20. (A) : From Einstein's photoelectric equation, maximum kinetic energy of phtoelectrons,

$K_{\max} = E - \phi = (5 - 3)\text{ eV} = 2$ eV

So, stopping potential, $V = 2$ V.

$\therefore$ $V = kq/r$

$$2 = 9\times10^9\,\frac{q}{8\times10^{-3}} \quad\text{or}\quad q = 1.78\times10^{-12}\,\text{C}$$

$$\text{So, } t = \frac{q}{10^5\times1.6\times10^{-19}} = \frac{1.78\times10^{-12}}{10^5\times1.6\times10^{-19}}$$

$t \approx 111$ sec or $t = 1.85$ min.

For other sections/subjects please refer to Chemistry Today and Biology Today

◆◆

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CBSE warm-up!

CLASS-XI

Chapterwise Practice Questions for CBSE Exams as per the latest pattern and reduced syllabus by CBSE for the academic session 2022-23.

Series-7

Oscillations | Waves

Time Allowed : 3 hours
Maximum Marks : 70

General Instructions :

(i) There are 35 questions in all. All questions are compulsory.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

(iii) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

(iv) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

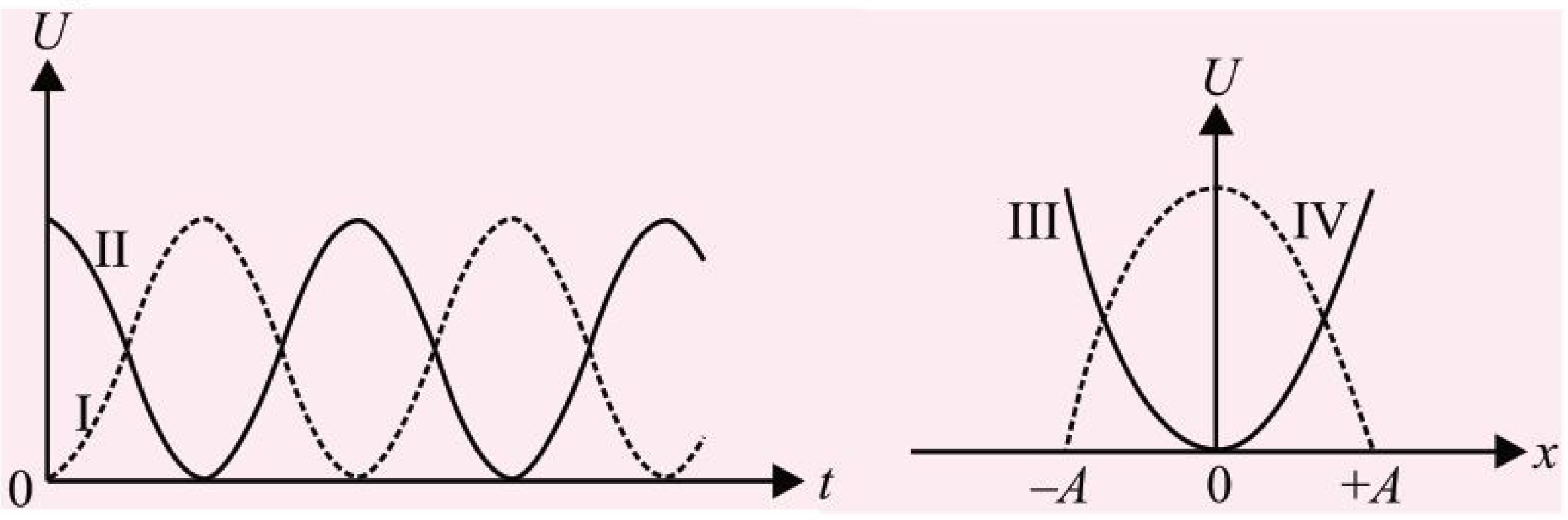
(v) Use of calculators is not allowed.

SECTION - A

1. If the frequency of human heart is 1.25 Hz, the number of heart beats in 1 minute is
(a) 65 (b) 75 (c) 80 (d) 90

2. Sound waves in air cannot be polarized because
(a) their speed is small (b) they require medium
(c) they are longitudinal
(d) their speed is temperature dependent

3. For a particle executing simple harmonic motion, the displacement x is given by $x = A\cos\omega t$. Identify the graph, which represents the variation of potential energy (U) as a function of time t and displacement x.



(a) I, III (b) II, III (c) I, IV (d) II, IV

4. A travelling harmonic wave on a string is described by $y = 7.5\sin(0.005x + 12t)$ in metre. Its time period in second is

(a) $\frac{\pi}{12}$ (b) $\frac{\pi}{6}$ (c) $\frac{\pi}{3}$ (d) $\frac{\pi}{2}$

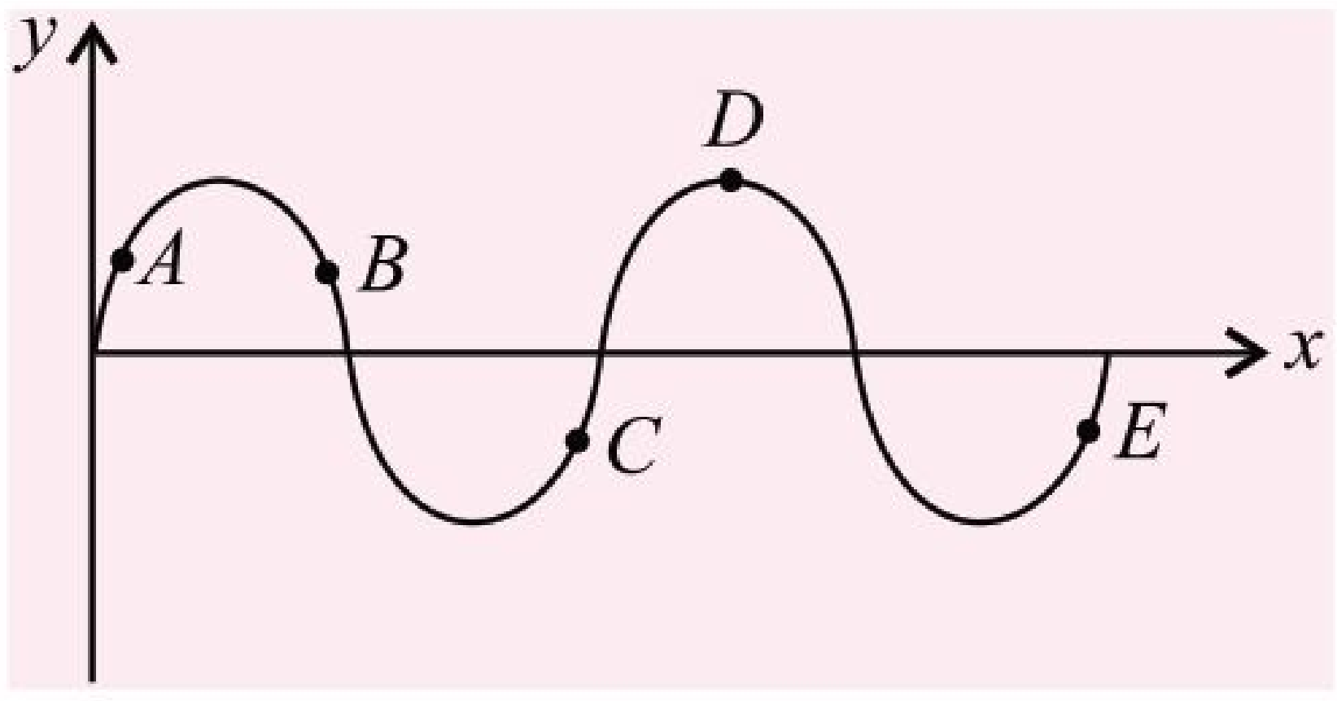
5. If a simple harmonic motion is represented by $\frac{d^2x}{dt^2} + \alpha x = 0$, its time period is

(a) $2\pi\sqrt{\alpha}$ (b) $2\pi\alpha$ (c) $\frac{2\pi}{\sqrt{\alpha}}$ (d) $\frac{2\pi}{\alpha}$

6. Resonance is an example of
(a) forced oscillation (b) damped oscillation
(c) free oscillation (d) none of these

7. A particle executing simple harmonic motion with an amplitude A. The distance travelled by the particle in $T/2$ seconds, where T is the time period of the SHM is
(a) zero (b) A (c) $2A$ (d) $4A$

8. Figure shows a sinusoidal wave at a given instant.



Which points are in phase?

(a) *A*, *B* (b) *B*, *C* (c) *B*, *D* (d) *C*, *E*

9. Two particles execute SHM of same amplitude and frequency on parallel lines. They pass one another when moving in opposite directions each time when their displacement is half of the amplitude. The phase difference between them is

(a) 0 (b) $\frac{2\pi}{3}$ (c) π (d) $\frac{\pi}{6}$

10. A 10 m long steel wire has mass 5 g. If the wire is under a tension of 80 N, the speed of transverse waves on the wire is

(a) 100 m s^{-1} (b) 200 m s^{-1}
(c) 400 m s^{-1} (d) 500 m s^{-1}

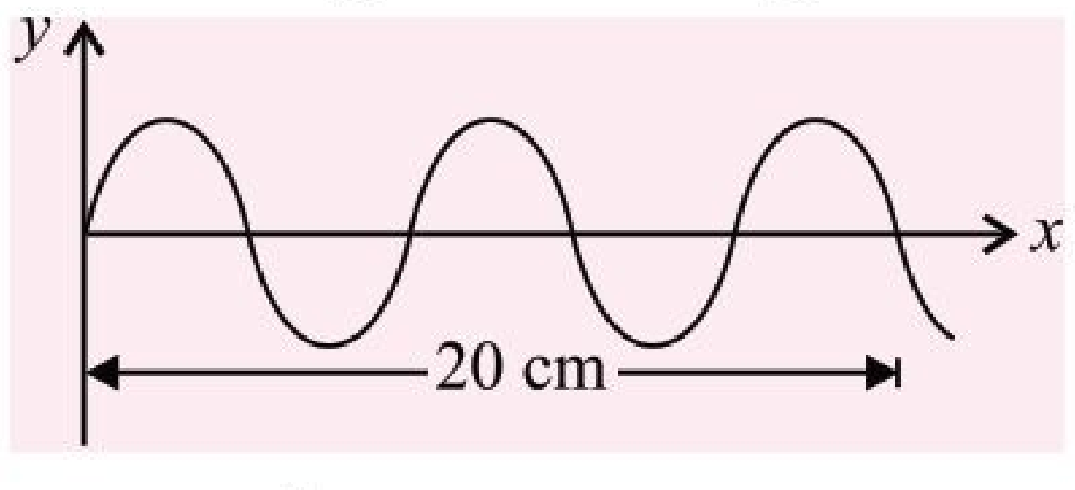
11. A 5 kg collar is attached to a spring of spring constant 500 N m^{-1}. It slides without friction over a horizontal rod. The collar is displaced from its equilibrium position by 10 cm and released. The time period of oscillation is

(a) $\frac{\pi}{5}$ s (b) $\frac{\pi}{2}$ s (c) π s (d) 2π s

12. Which one of the following statements is true for the velocity *v* and the acceleration *a* of a particle executing simple harmonic motion?

(a) When *v* is maximum, *a* is zero.
(b) When *v* is zero, *a* is zero.
(c) When *v* is maximum, *a* is maximum.
(d) Value of *a* is zero, whatever may be the value of *v*.

13. Figure given shows a sinusoidal wave on a string. If the frequency of the wave is 150 Hz, what is the velocity and wavelength of the given wave?



(a) 0.04 m, 10 m s^{-1} (b) 0.06 m, 12 m s^{-1}
(c) 0.08 m, 10 m s^{-1} (d) 0.08 m, 12 m s^{-1}

14. In simple harmonic motion, at the extreme positions

(a) kinetic energy is minimum, potential energy is maximum.
(b) kinetic energy is maximum, potential energy is minimum.
(c) both kinetic and potential energies are maximum.
(d) both kinetic and potential energies are minimum.

15. Which of the following is incorrect?

(a) If the wave is longitudinal, it must be a mechanical wave.
(b) If the wave is mechanical, it may or may not be transverse wave.
(c) Mechanical waves cannot propagate in vacuum.
(d) Diffraction helps us to distinguish between sound wave and light wave.

For question numbers 16-18, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true and R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

16. Assertion : A block of small mass *m* attached to a stiff spring will have large oscillation frequency.
Reason : Stiff springs have high value of spring constant.

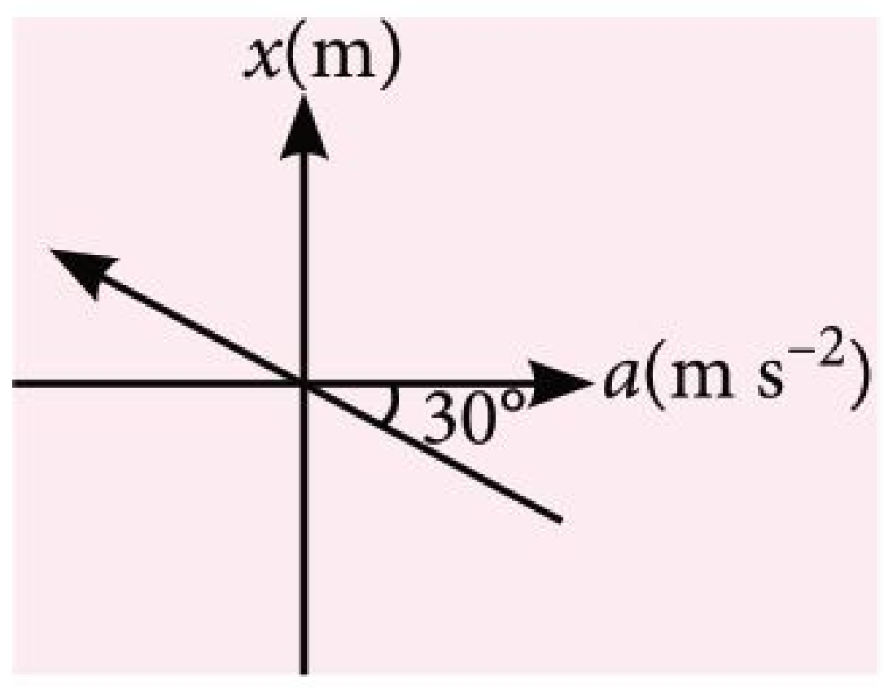
17. Assertion : The fundamental frequency of an open organ pipe increases as the temperature is increased.
Reason : As the temperature increases the velocity of sound increases more rapidly than length of pipe.

18. Assertion : In a progressive longitudinal wave, the amplitude of the wave will not be the same at all points of the medium along the direction of propagation of the wave.

Reason : There is a discontinuous change of the phase angle of the wave as it progressive in the direction of motion.

SECTION - B

19. Figure shows the acceleration-displacement graph of a particle in SHM. Find the time period (in second).



20. Find the period of vibrating particle (SHM), which has acceleration of 45 cm s^{-2}, when displacement from mean position is 5 cm.

21. Explain, why can we not hear an echo in a small room?

22. Three springs of constants k_1, k_2 and k_3 are connected end to end and are used to hang a mass M from the roof. Determine the elastic potential energy stored in the array.

23. In an open organ pipe, third harmonic is 450 Hz. What is the frequency of fifth harmonic?

24. Define S.H.M. What are its chracteristics? At what distance from the mean position in S.H.M of amplitude r, the energy is half kinetic and half potential ?

OR

What do you understand by phase of a wave? How does the phase change with time and position?

25. Differentiate between the wave velocity and particle velocity.

OR

What are the differences between stationary waves and progressive waves?

SECTION - C

26. The velocity of sound, under STP conditions, equal 400 m/s. What will be the velocity when the

(i) pressure is changed to 2 atmospheric pressure without any change in temperature?

(ii) temperature is increased to 819 °C?

27. Two particles are executing SHM with same amplitudes A and time period T. When one of the particles is located at extreme right, the other particle is located at mean position and moving towards left. From this instant, find the time after which both the particles will have same displacement from the equilibrium position.

28. With reference to wave motion define the terms

(i) amplitude
(ii) wavelength
(iii) time period
(iv) frequency
(v) Wave speed

OR

The equations of displacement of two waves are $y_1 = 10\sin\left[3\pi t + \frac{\pi}{3}\right]$ and $y_2 = 5[\sin 3\pi t + \sqrt{3}\cos 3\pi t]$.

Find the ratio of their amplitudes.

29. A sitar wire is under tension of 40 N and the length between the bridge is 70 m. A 5 m sample of that wire has mass 1.0 g. Determine :

(i) the speed of transverse waves on the wire
(ii) frequency of the fundamental and
(iii) the frequencies of the first two harmonics.

OR

A body oscillates with SHM according to the equation (in SI unit)

$$x = 5\cos\left[2\pi t + \frac{\pi}{4}\right]$$

At t = 1.5 seconds, calculate (i) displacement, (ii) speed.

30. Explain simple harmonic motion with reference to uniform circular motion with the help of diagram.

SECTION - D

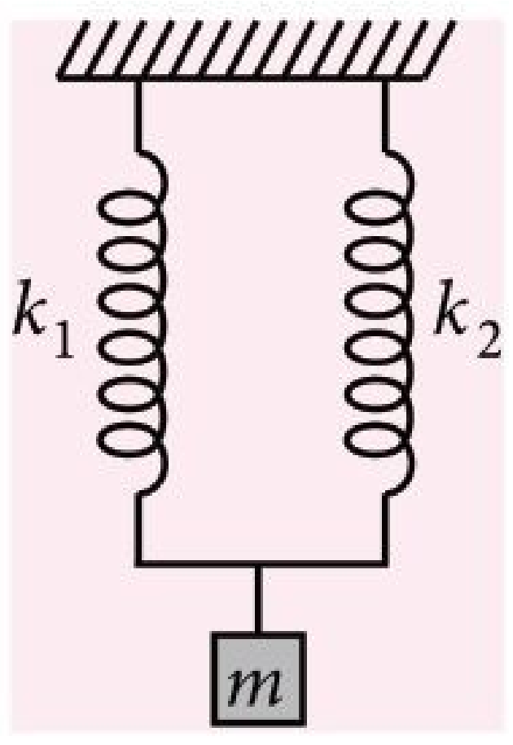
31. **(i)** Draw a graph showing the variation of kinetic energy and potential energy of a particle executing SHM with its displacement from mean position.

(ii) A particle is performing simple harmonic motion with angular frequency 5000 rad/s and amplitude 2 cm and mass of 1 kg. Find the total energy of oscillation.

OR

(i) One end of a U-tube containing mercury is connected to a suction pump and the other end to atmosphere. A small pressure difference is maintained between the two columns. Show that when the suction pump is removed, the liquid column of mercury in the U-tube executes SHM.

(ii) An arrangement of springs for SHM is shown in figure. If mass of block is m, then find frequency of oscillation.



32. Discuss Newton's formula for velocity of sound in gases and apply Laplace's correction.

OR

(i) What do we understand by the terms nodes and antinodes for a stationary wave?

(ii) Obtain an expression, for the frequency of vibration, for the first normal mode of vibration, of a string of length L, fixed at two ends.

(iii) Also obtain the expression, for the frequency of the second mode of vibration for the same string.

33. **(i)** What are stationary waves? Discuss the characteristics.

(ii) Distinguish between harmonics and overtones.

OR

(i) Explain the formation of beats by analytical method and find the beat frequency.

(ii) Explain some practical applications of beat phenomenon.

SECTION - E

34. Read the following paragraph and answer the questions.

Case Study : Motion of a pendulum

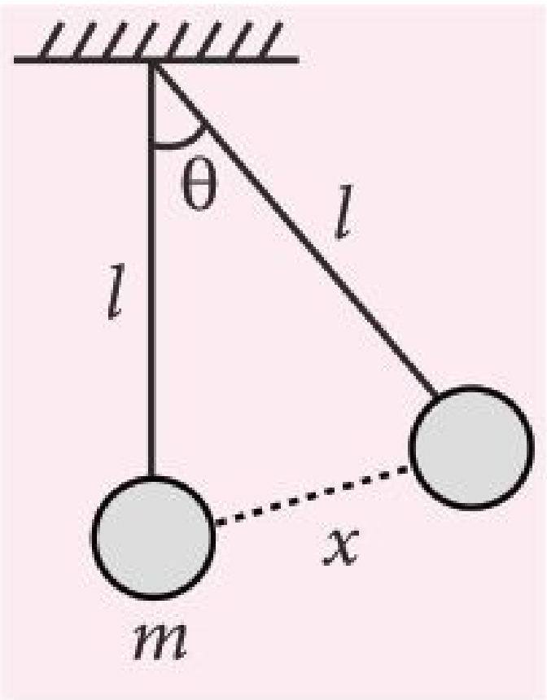
When the metallic bob of mass m is displaced slightly on either side and released, it begins to oscillate about the mean position. If the thread makes angle θ with the vertical at any instant, then the magnitude of force acting on the bob is

$|\vec{F}| = mg \sin\theta$

For small displacement x,

$\sin\theta \approx \theta = \frac{x}{l}$

This implies that motion of the pendulum is simple harmonic.



(i) When a simple pendulum is moved from the Earth's surface to deep mine, what will be the effect on period of oscillation ?

(ii) Calculate the time period of a simple pendulum of length 9.8 m.

(iii) A simple pendulum of length l has maximum angular displacement θ. Find the maximum kinetic energy of the bob of mass m.

OR

Two simple pendulums A and B are made to oscillate simultaneously and it is found that A completes 10 oscillations in 20 s and B completes 8 oscillations in 10 s. Find the ratio of the lengths of A and B.

35. Read the following paragraph and answer the questions.

Case Study : Newton's Formula

Newton assumed that sound travels through a gas under isothermal conditions. So, Newton's formula for the speed of sound in a gas is

$v = \sqrt{\frac{k_{iso}}{\rho}} = \sqrt{\frac{P}{\rho}}$, where P = pressure of the gas

In 1816, Laplace pointed out that sound travels through a gas under adiabatic conditions.

(i) The velocity of sound in air at NTP is 330 m/s. What will be its value (in m/s) when temperature is doubled and pressure is halved?

(ii) Name the factor on which velocity of sound (in any gas) depends.

(iii) The speed of sound in oxygen (O_2) at a certain temperature is 460 m/s. Find the speed (in m/s) of sound in helium (He) at the same temperature (assume both the gases to be ideal).

OR

The velocity of sound at the same temperature in two monoatomic gases of densities ρ_1 and ρ_2 are v_1 and v_2 respectively. If $\rho_1/\rho_2 = 4$, then find the value of v_1/v_2.

SOLUTIONS

1. (b) : Beat frequency of heart = 1.25 Hz

∴ Number of beats in 1 minute = 1.25 × 60 = 75

2. (c) : Sound waves are longitudinal waves that is why in air they cannot be polarized.

3. (d) **4. (b)**

5. (c) : The equation of SHM,

$$\frac{d^2x}{dt^2} + \alpha x = 0 \text{ or } \frac{d^2x}{dt^2} = -\alpha x$$

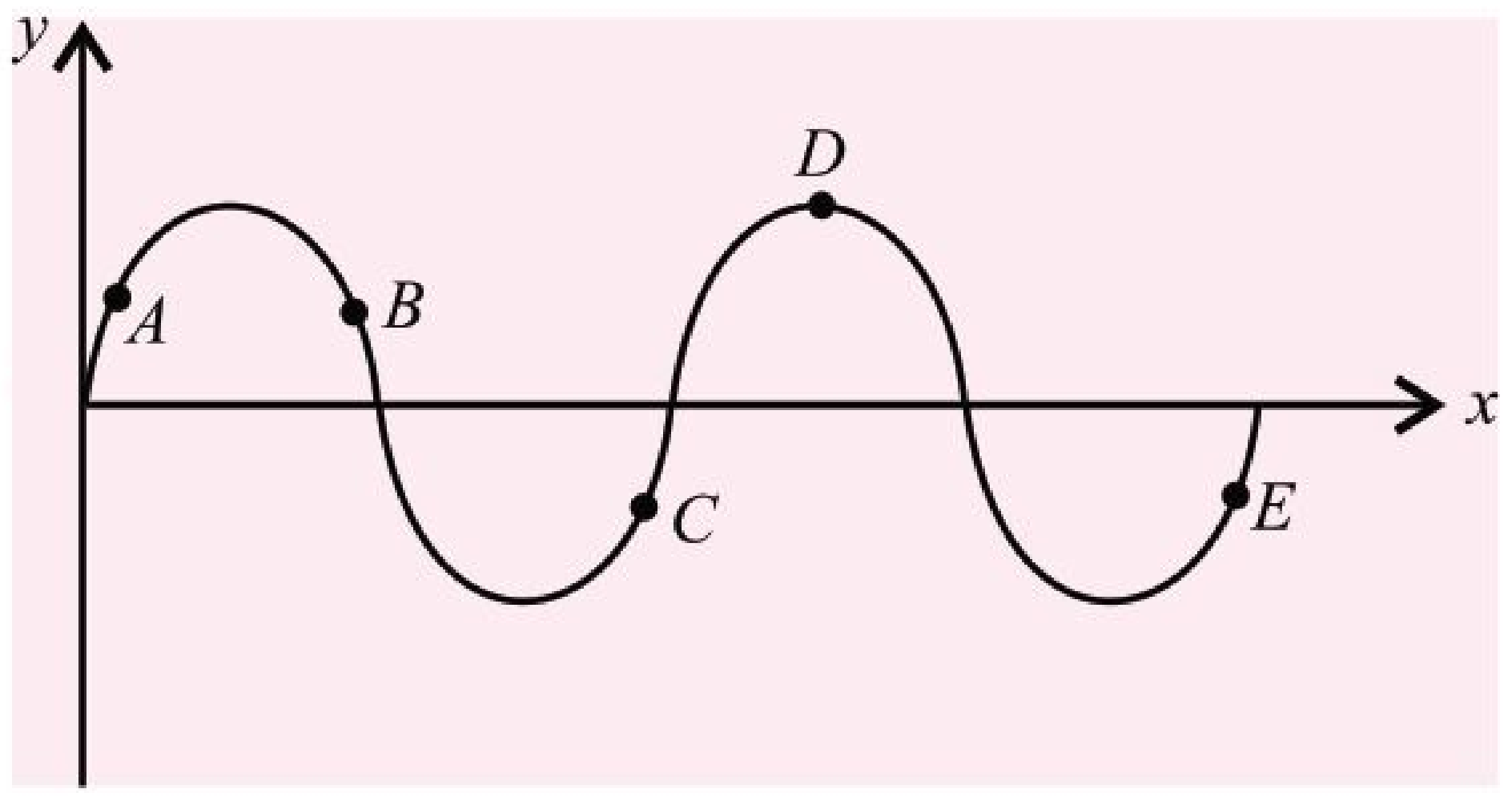
Comparing it with the equation of SHM

$$\frac{d^2x}{dt^2} = -\omega^2 x \;;\; \omega^2 = \alpha \text{ or } \omega = \sqrt{\alpha} \;;\; \therefore\; T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\alpha}}.$$

6. (a) : Resonance is an example of forced oscillation.

7. (c) : The distance travelled by the particle in one time period is $2A$.

8. (d) :



In the given figure, points C and E are in the same phase.

9. (b) **10. (c)**

11. (a) : Here, $m = 5$ kg, $k = 500$ N m^{-1}, $A = 10$ cm $= 0.1$ m

Time period of oscillation is

$$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{5 \text{ kg}}{500 \text{ N m}^{-1}}} = \frac{2\pi}{10} \text{ s} = \frac{\pi}{5} \text{ s}$$

12. (a) : In SHM, velocity $v = \omega\sqrt{A^2 - x^2}$

Acceleration, $a = -\omega^2 x$

When $x = 0$, $v = \omega A$ = maximum and $a = 0$

When $x = A$, $v = 0$ and $a = -\omega^2 A$ = maximum

13. (d)

14. (a) : In SHM, kinetic energy is maximum at mean position and zero at the extreme positions while potential energy is zero at mean position and maximum at the extreme positions.

15. (d) : Polarisation helps us to distinguish between sound wave and light wave.

16. (a) : Angular frequency, $\omega=\sqrt{\frac{k}{m}}$

As stiff springs have high value of k, so the block will oscillate with large oscillation frequency.

17. (a)

18. (d) : Amplitude of a progressive longitudinal wave is the same at all points of a medium, assuming there is no attenuation. It is the instantaneous displacement of a particle from the mean position that differ and depends upon the phase angle of the wave.

19. The slope of given graph is

$$-\tan 30° = -1/\sqrt{3}$$

$$\therefore \quad \frac{x}{a}=-\frac{1}{\sqrt{3}}$$

We know in SHM, $a = -\omega^2 x \Rightarrow \frac{x}{a}=-\frac{1}{\omega^2}$

$$\therefore \quad \frac{1}{\omega^2}=\frac{1}{\sqrt{3}} \Rightarrow \omega = 3^{1/4} \qquad \therefore \quad T=\frac{2\pi}{3^{1/4}}$$

20. Here $y = 5$ cm and acceleration $a = 45$ cm s^{-2}

We know $a = \omega^2 y$

$$\therefore \quad 45 = \omega^2 \times 5 \quad \text{or} \quad \omega = 3 \text{ rad s}^{-1}$$

And $T=\frac{2\pi}{\omega}=\frac{2\pi}{3}=2.0935$ s

21. For an echo of a simple sound to be heard, the minimum distance between the speaker and the walls should be 17 m, so in any room having length less than 17 m, our ears can not distinguish between sound received directly and sound received after reflection due to persistence of hearing. The sensation of hearing of any sound persists in our brain for 0.1 s.

22. $y=\frac{Mg}{k}, U=\frac{1}{2}ky^2=\frac{1}{2}k\frac{M^2g^2}{k^2}=\frac{1}{2}\cdot\frac{M^2g^2}{k}$

$\therefore$ Total potential energy is $U = U_1 + U_2 + U_3$

$$\text{or} \quad U=\frac{1}{2}M^2g^2\left(\frac{1}{k_1}+\frac{1}{k_2}+\frac{1}{k_3}\right)$$

23. Frequency of the 3rd harmonic = $3\upsilon_1 = 450$ Hz where υ_1 is the frequency of the fundamental harmonic of the open organ pipe.

Frequency of the 5th harmonic = $5\upsilon_1$

$3\upsilon_1 = 450 \text{ Hz} \Rightarrow \upsilon_1 = 150 \text{ Hz}$

$5\upsilon_1 = 150 \times 5 = 750 \text{ Hz}$

Therefore frequency of the fifth harmonic is 750 Hz.

24. A particular type of periodic motion in which a particle moves to and fro repeatedly about a mean position under the influence of a restoring force is termed as simple harmonic motion (SHM).

A body is undergoing simple harmonic motion if it has an acceleration which is

- directed towards a fixed point, and
- proportional to the displacement of the body from that point.

  acceleration $a \propto -x \Rightarrow a = -kx$

  or $\frac{d^2x}{dt^2} = -kx$, where x = displacement at any instant t.

Energy, $E_k=\frac{1}{2}m\omega^2(a^2-x^2)$,

(Here a is amplitude of motion)

$$E_p=\frac{1}{2}m\,\omega^2x^2$$

As, $E_k = E_p$

$$\therefore \quad \frac{1}{2}m\,\omega^2(a^2-x^2)=\frac{1}{2}m\,\omega^2x^2$$

$$\text{or} \quad 2x^2 = a^2 \quad \text{or} \quad x=\pm\frac{a}{\sqrt{2}}$$

OR

The quantity $(kx - \omega t + \phi)$ appearing as the argument of sine function in general equation of wave is called the phase of the wave.

$y(x, t) = a \sin(kx - \omega t + \phi)$.

The phase determines the displacement of the wave at any position and at any instant. Clearly, ϕ is the phase at $x = 0$ and $t = 0$. ϕ is called initial phase angle. By suitable choice of origin on the x-axis and the initial time, it is possible to have $\phi = 0$.

25.

Wave velocity	**Particle velocity**
The velocity with which wave travels in space is called wave velocity. $v = \upsilon\lambda$	The velocity with which the particles are vibrating to transfer the energy in the form of a wave is called particle velocity.
It remains constant (keeping density of medium, frequency of source constant)	It depends on the time.

OR

	Stationary waves	Progressive waves
(i)	The disturbance remains confined to a particular region, and there is no onward motion.	The disturbance travels forward, being handed over from one particle to the neighbouring particles.
(ii)	There is no transfer of energy in the medium.	Energy is transferred in the medium along the waves.
(iii)	The amplitude of vibration of particles varies from zero at nodes to maximum at antinodes.	The amplitude of vibration of each particle is same.

26. (i) Pressure $P_1 = 1.013 \times 10^5$ N m^{-2}; velocity, $v_1 = 400$ m s^{-1}

When pressure $P_2 = 2 \times 1.013 \times 10^5$ N m^{-2},

At constant temperature, $\frac{P}{\rho} = \text{constant}$

$\therefore$ Velocity, $v_2 = v_1 = 400$ m s^{-1}

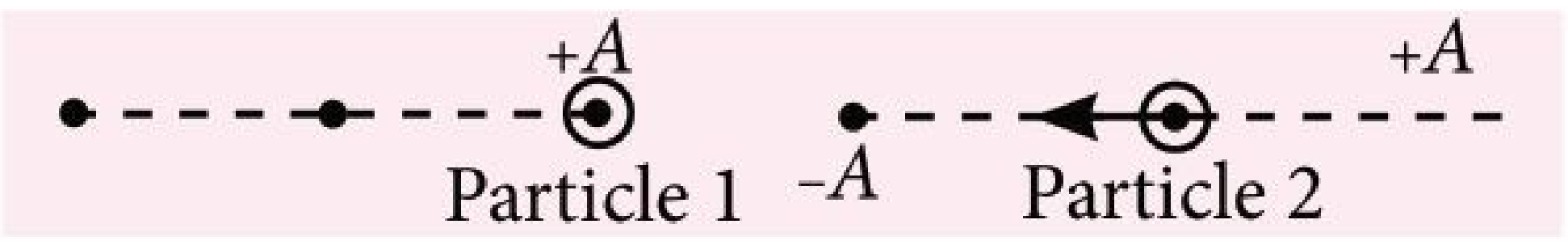
(ii) Velocity, $v_1 = 400$ m s^{-1} at temperature $T_1 = 273$ K.

When temperature, $T_2 = 819 + 273 = 1092$ K, then velocity is v_2.

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} \quad \text{or} \quad \frac{400}{v_2} = \sqrt{\frac{273}{1092}}$$

$$\frac{400}{v_2} = \frac{1}{2} \quad \text{or} \quad v_2 = 800 \text{ m s}^{-1}$$

27. If this instant is taken as $t = 0$. Then, initial phase for particle (1) is $\delta_1 = \frac{\pi}{2}$ and initial phase for particle (2) is $\delta_2 = \pi$.



$$\therefore \quad x_1 = A\sin\left(\omega t + \frac{\pi}{2}\right) \text{ and } x_2 = A\sin(\omega t + \pi)$$

When both of them have same displacement, $x_1 = x_2$

$$\therefore \quad A\sin\left(\omega t + \frac{\pi}{2}\right) = A\sin(\omega t + \pi)$$

or $\cos \omega t = -\sin\omega t$ or $\tan\omega t = -1$

$$\text{or} \quad \frac{3\pi}{4} = \omega t \quad \text{or} \quad \frac{2\pi}{T}t = \frac{3\pi}{4} \Rightarrow t = \frac{3T}{8}$$

28. Terms related to wave motion:

(i) **Amplitude:** It is defined as the maximum displacement of an oscillating particle of the medium from the mean position. It is denoted by symbol A.

(ii) **Wavelength :** It is defined as the distance travelled by the wave during the time, the particle of the medium completes one oscillation about its mean position. It may also be defined as the distance between two consecutive points in the same phase of wave motion. It is denoted by symbol λ.

In case of transverse wave,

λ = distance between two consecutive crests or troughs.

In case of longitudinal waves,

λ = distance between two consecutive compressions or rarefactions.

(iii) **Time period :** It is defined as the time taken by a particle to complete one oscillation about its mean position. It is denoted by symbol T.

(iv) **Frequency :** It is defined as the number of oscillations made by the particle in one second. It is denoted by symbol υ.

$$\upsilon = \frac{1}{T}$$

(v) **Wave speed or speed of a wave :** It is defined as the distance travelled by the wave in one second. It is denoted by symbol v and is given by

$$v = \upsilon\lambda$$

OR

Here, $y_1 = 10\sin\left(3\pi t + \frac{\pi}{3}\right)$

$\therefore$ Amplitude of this wave is, $A_1 = 10$

and $y_2 = 5[\sin 3\pi t + \sqrt{3}\cos 3\pi t]$

$$= 10\left[\frac{1}{2}\sin 3\pi t + \frac{\sqrt{3}}{2}\cos 3\pi t\right]$$

$$= 10\left[\cos\frac{\pi}{3}\sin 3\pi t + \sin\frac{\pi}{3}\cos 3\pi t\right] = 10\sin\left(3\pi t + \frac{\pi}{3}\right)$$

$\therefore$ Amplitude of this wave is, $A_2 = 10$

Their corresponding ratio is $\frac{A_1}{A_2} = \frac{10}{10} = 1$

29. Here, tension, $T = 40$ N;

Mass of 5 m wire $= 1 \times 10^{-3}$ kg

Length of string between bridges, $L = 70$ cm.

(i) Speed of transverse waves,

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{40 \times 5}{1 \times 10^{-3}}} \approx 447 \text{ ms}^{-1}$$

(ii) Frequency of fundamental, $\upsilon = \frac{v}{2L}$

$$= \frac{1}{2 \times 70} \times 447 \times 100 \approx 320 \text{ Hz}$$

(iii) Frequencies of first two harmonics are υ and 2υ *i.e.*, 320 Hz, 640 Hz

OR

Given, $x = 5\cos(2\pi t + \pi/4)$

(i) Displacement at $t = 1.5$ seconds is

$$x = 5\cos[(2\pi \times 1.5) + \pi/4]$$

$$= \left[5\cos\left(3\pi + \frac{\pi}{4}\right)\right] = -5\cos\frac{\pi}{4} = \frac{-5}{\sqrt{2}}\text{ m}$$

(ii) Speed, $v = \frac{dx}{dt} = -(5 \times 2\pi)\sin(2\pi t + \pi/4)$

$$= -10\pi\sin(2\pi t + \pi/4)$$

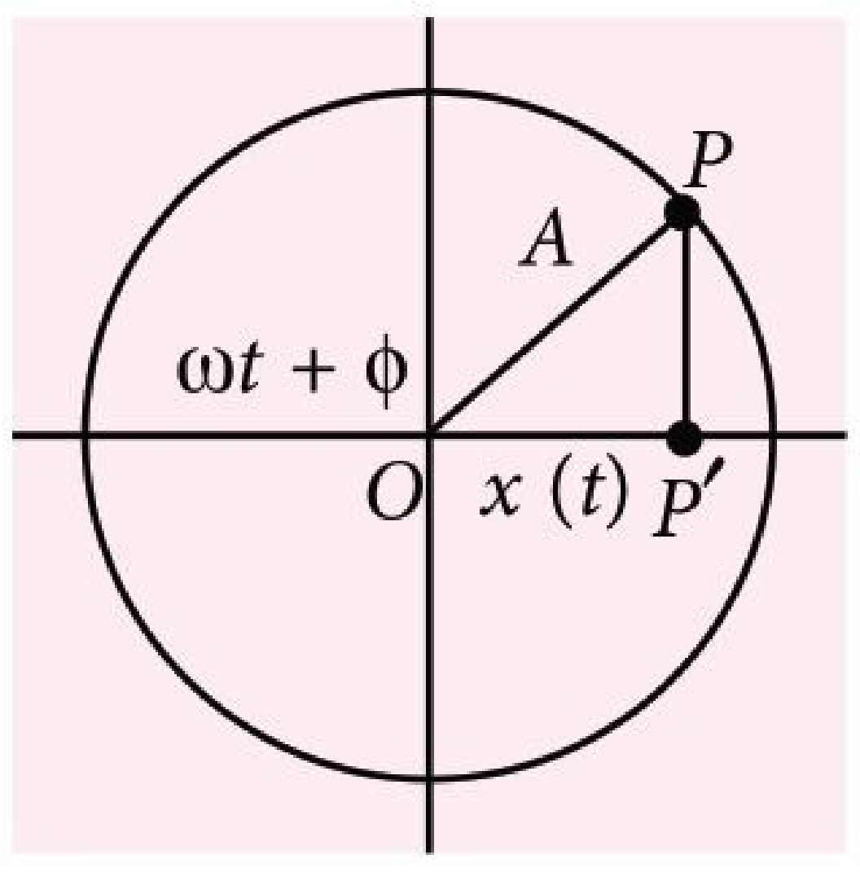
$\therefore$ Speed at $t = 1.5$ seconds is

$$v = -10\pi\sin[(2\pi \times 1.5) + \pi/4]$$

$$= -10\pi\sin\left[3\pi + \frac{\pi}{4}\right] = -10\pi \times \left(-\sin\frac{\pi}{4}\right)$$

$$= \frac{10\pi}{\sqrt{2}} = \frac{10\sqrt{2}\pi}{2} = 5\sqrt{2}\,\pi\text{ m s}^{-1}$$

30. The motion of a reference particle P executing a uniform circular motion with constant angular speed ω in a reference circle is shown in the figure. The radius A of the circle is the magnitude of the particle position vector.



At any time t, the angular position of the particle is $(\omega t + \phi)$, where ϕ is its angular position at $t = 0$.

The projection of particle P on the x-axis is a point P', which we can take as a second particle. The projection of the position vector of particle P on the x-axis gives the location $x(t)$ of P'.

Thus we have, $x(t) = A\cos(\omega t + 0)$.

This shows that if the reference particle P moves in a uniform circular motion, its projection particle P' executes a simple harmonic motion along diameter of the circle. This Simple harmonic motion is the projection of uniform circular motion on a diameter of the circle in which the latter motion takes place.

31. *Refer to answer 19, Page no. 614-615, Class-11, MTG 100 percent Physics.*

OR

Refer to answer 25, Page no. 628-629, Class-11, MTG 100 percent Physics.

32. *Refer to answer 19, Page no. 667, Class-11, MTG 100 percent Physics.*

OR

Refer to answer 32, Page no. 688-689, Class-11, MTG 100 percent Physics.

33. *Refer to answer 28 Page no. 686-687, Class-11, MTG 100 percent Physics.*

OR

Refer to answer 31, Page no. 688, Class-11, MTG 100 percent Physics.

34. (i) As we move from Earth's surface to deep mine, the acceleration due to gravity decreases and hence the time period of oscillation of a simple pendulum increases.

Since, $T = 2\pi\sqrt{\frac{l}{g}}$

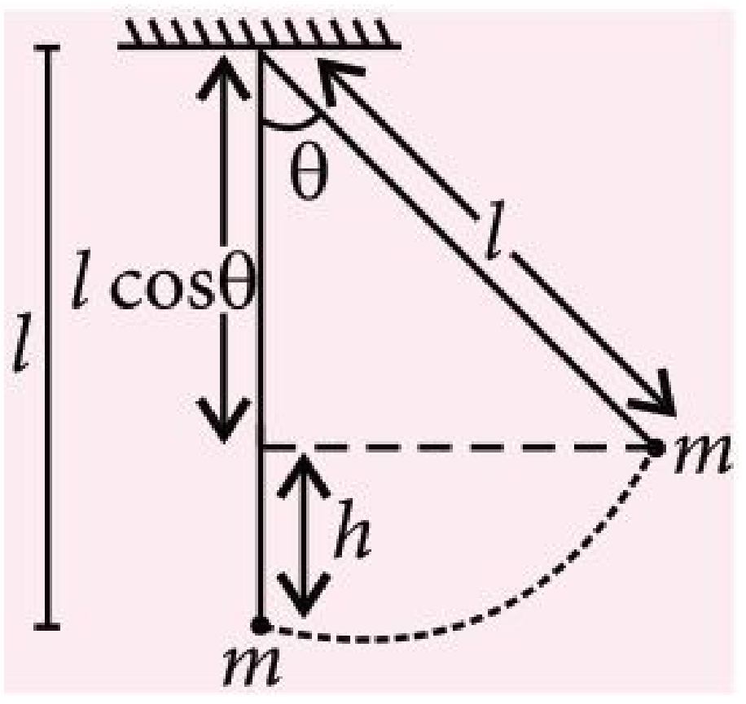
$\therefore$ As g decreases, T increases.

(ii) Time period of a simple pendulum, $T = 2\pi\sqrt{\frac{l}{g}}$

Here, $l = 9.8$ m, $g = 9.8\text{ m/s}^2$

$$\therefore \quad T = 2 \times 3.14\sqrt{\frac{9.8}{9.8}} = 6.28\text{ sec}$$

(iii) Refer to figure.



Maximum kinetic energy of the bob

= total energy of the bob

= maximum potential energy of the bob

$= mgh = mg\,(l - l\cos\theta)$

$= mgl\,(1 - \cos\theta)$

where g is the acceleration due to gravity.

OR

Frequency of oscillations made by a simple pendulum of length l is $\upsilon = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \Rightarrow \upsilon \propto \frac{1}{\sqrt{l}}$

Since, A completes 10 oscillations in 20 s

$\upsilon_A = \frac{10}{20} = 0.5\text{ Hz}$. Similarly, $\upsilon_B = \frac{8}{10} = 0.8\text{ Hz}$

$$\therefore \quad \frac{\upsilon_A}{\upsilon_B} = \frac{5}{8} = \sqrt{\frac{l_B}{l_A}} \quad \text{or} \quad \frac{l_A}{l_B} = \frac{64}{25}$$

35. (i) Pressure has no effect on the velocity of sound. As, $v \propto \sqrt{T}$, when temperature is doubled, velocity becomes $330\sqrt{2}$ m/s.

(ii) The velocity of sound in a gas depends on density and elasticity of the gas.

(iii) $\frac{v_{He}}{v_{O_2}} = \sqrt{\frac{\gamma_{He}}{\gamma_{O_2}} \cdot \frac{M_{O_2}}{M_{He}}} = \sqrt{\frac{5/3}{7/5} \cdot \frac{32}{4}} = \sqrt{\frac{200}{21}} = 3.086$

$$= \sqrt{\frac{5/3}{7/5} \cdot \frac{32}{4}} = \sqrt{\frac{200}{21}} = \sqrt{9.52} = 3.086$$

$v_{He} = 3.086 \times v_{O_2} = 3.086 \times 460 = 1420$ m/s.

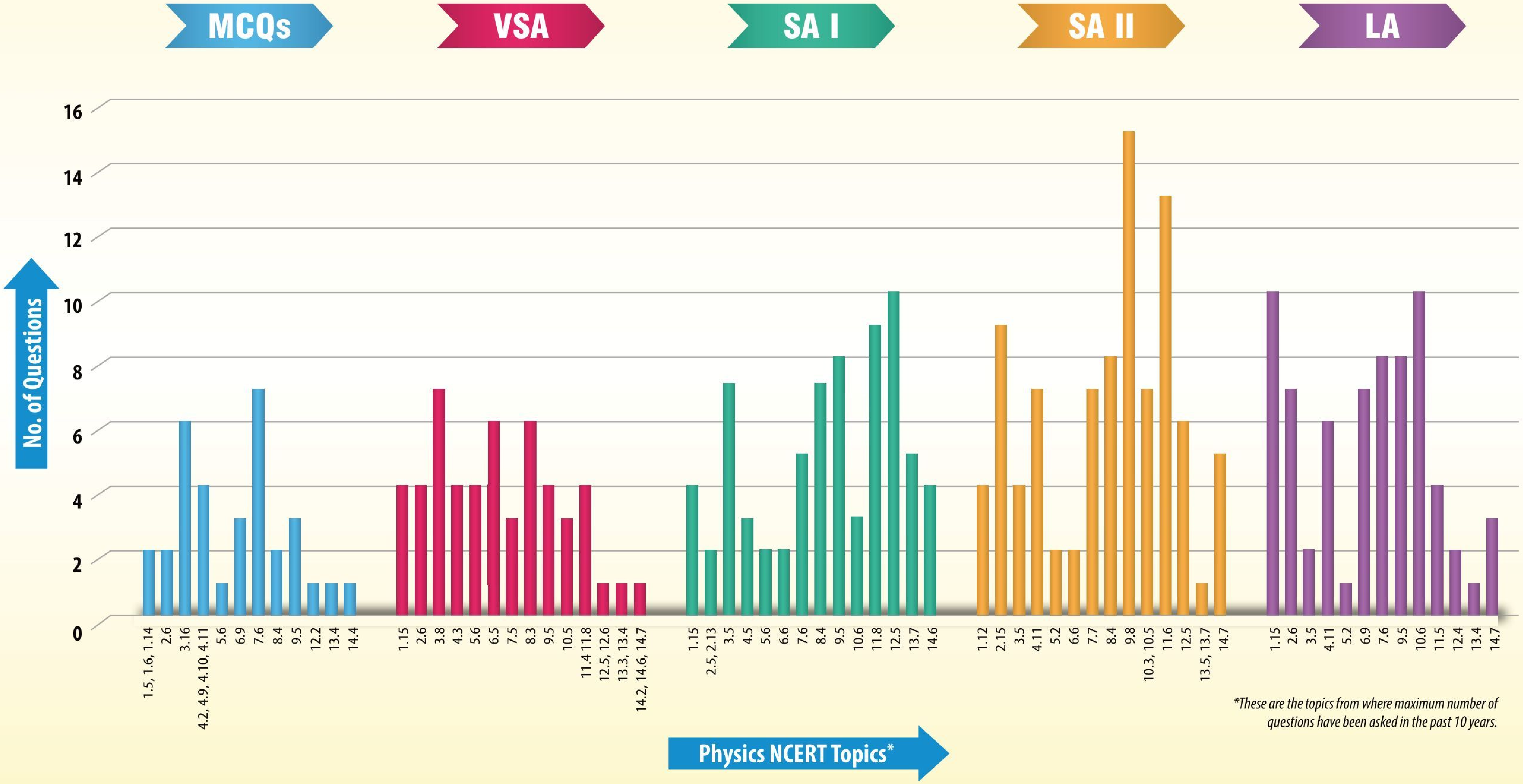
OR

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad i.e., v \propto \frac{1}{\sqrt{\rho}} \quad \therefore \quad \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

◆◆

Are You Ready for CBSE Board Exams?

Past 10 Years (2013-2022) Chapterwise and Topicwise Trend Analysis of CBSE Board Questions



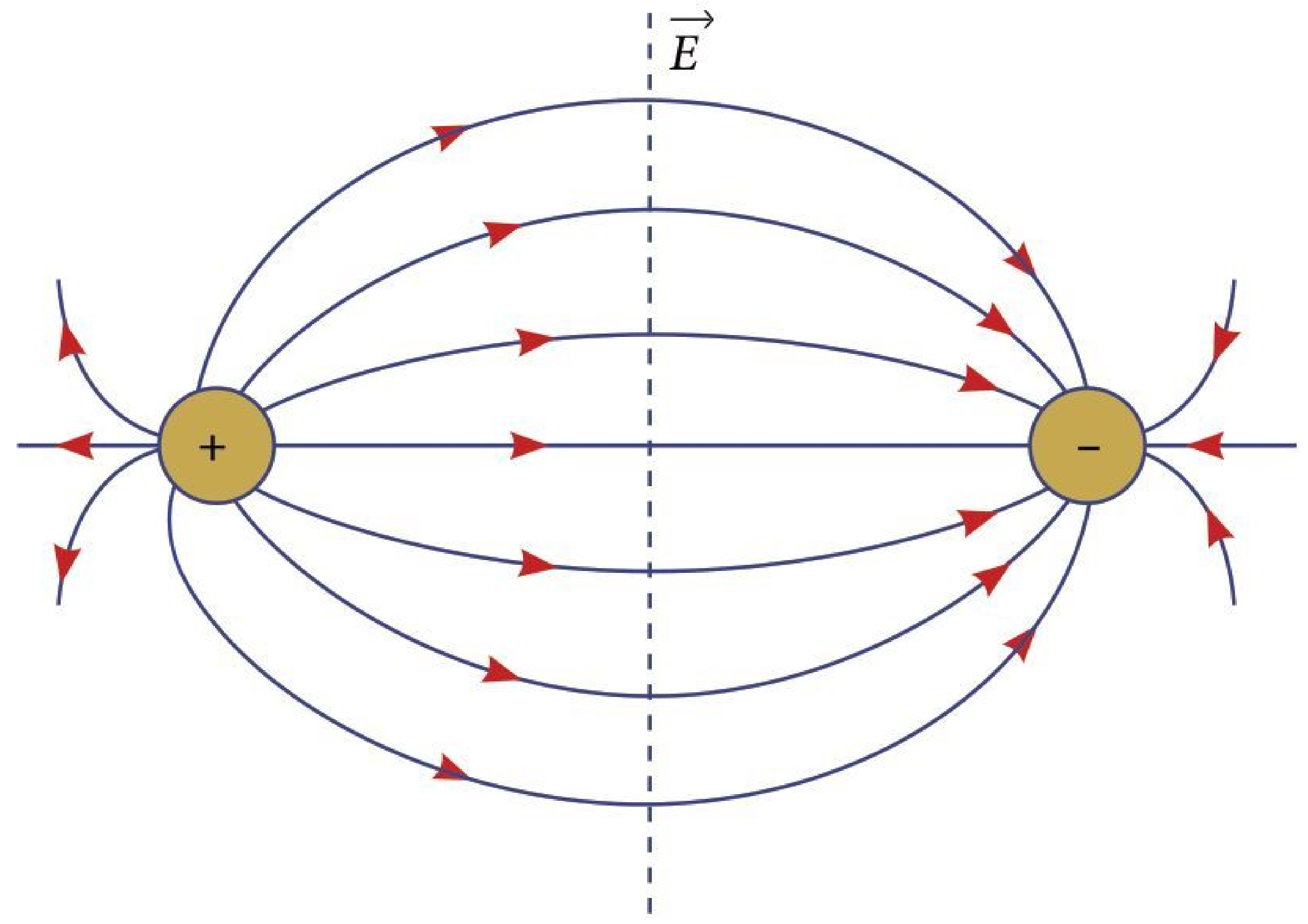
*These are the topics from where maximum number of questions have been asked in the past 10 years.

Some of the important topics extracted from the graphical analysis are explained here with HD images.

01 | Electric Charges and Fields

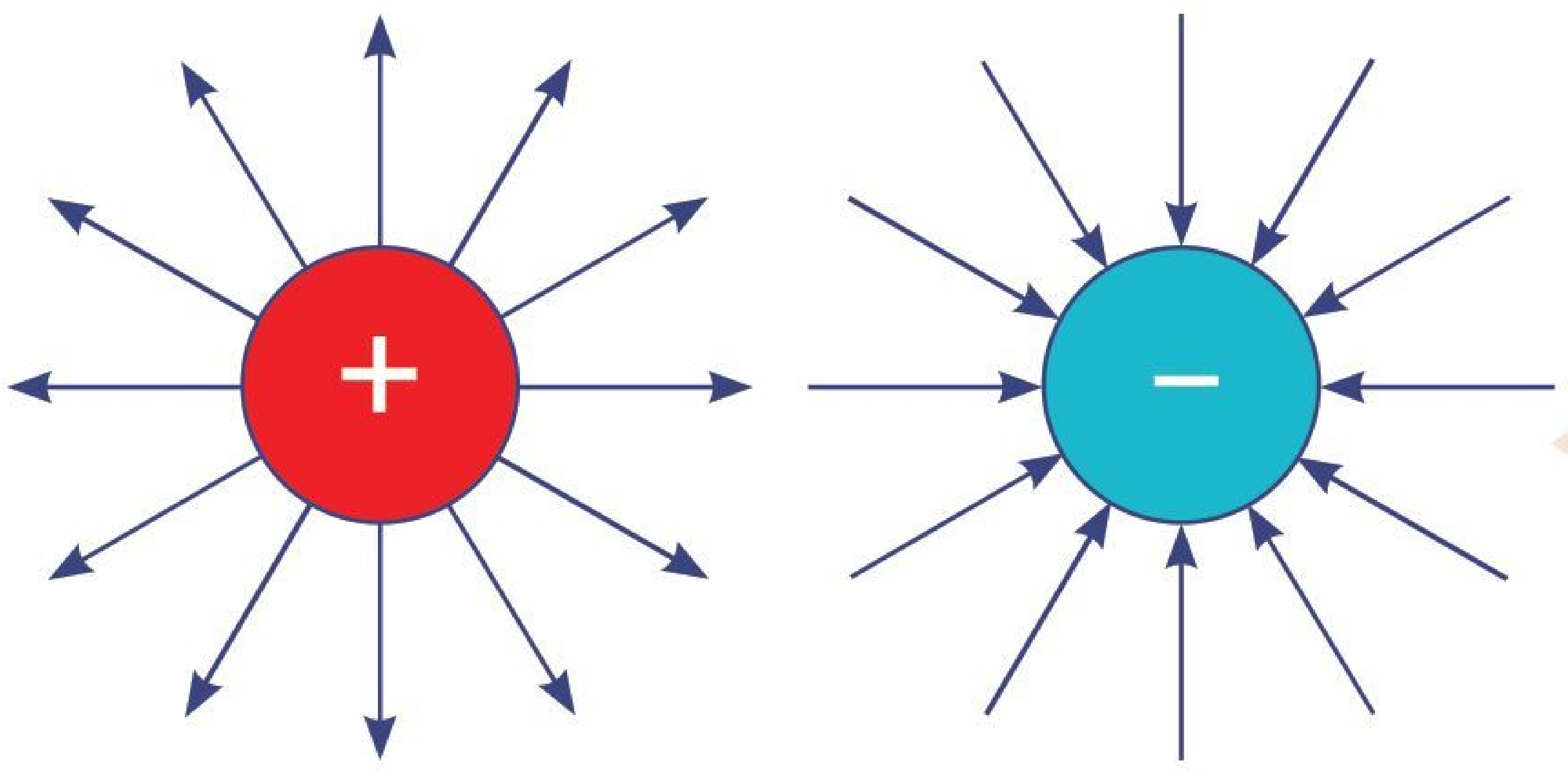
Electric Dipole

Field lines of two equal and opposite point charges shows the electric lines of force of an electric dipole *i.e.*, a system of two equal and opposite point charges separated by a small distance. They start from the positive charge and end on the negative charge. The lines of force seems to contract lengthwise as if the two charges are being pulled together. This explains attraction between two unlike charges. The field is cylindrically symmetric about the dipole axis *i.e.*, the field pattern is same in all planes passing through the dipole axis.



Electric Field Lines

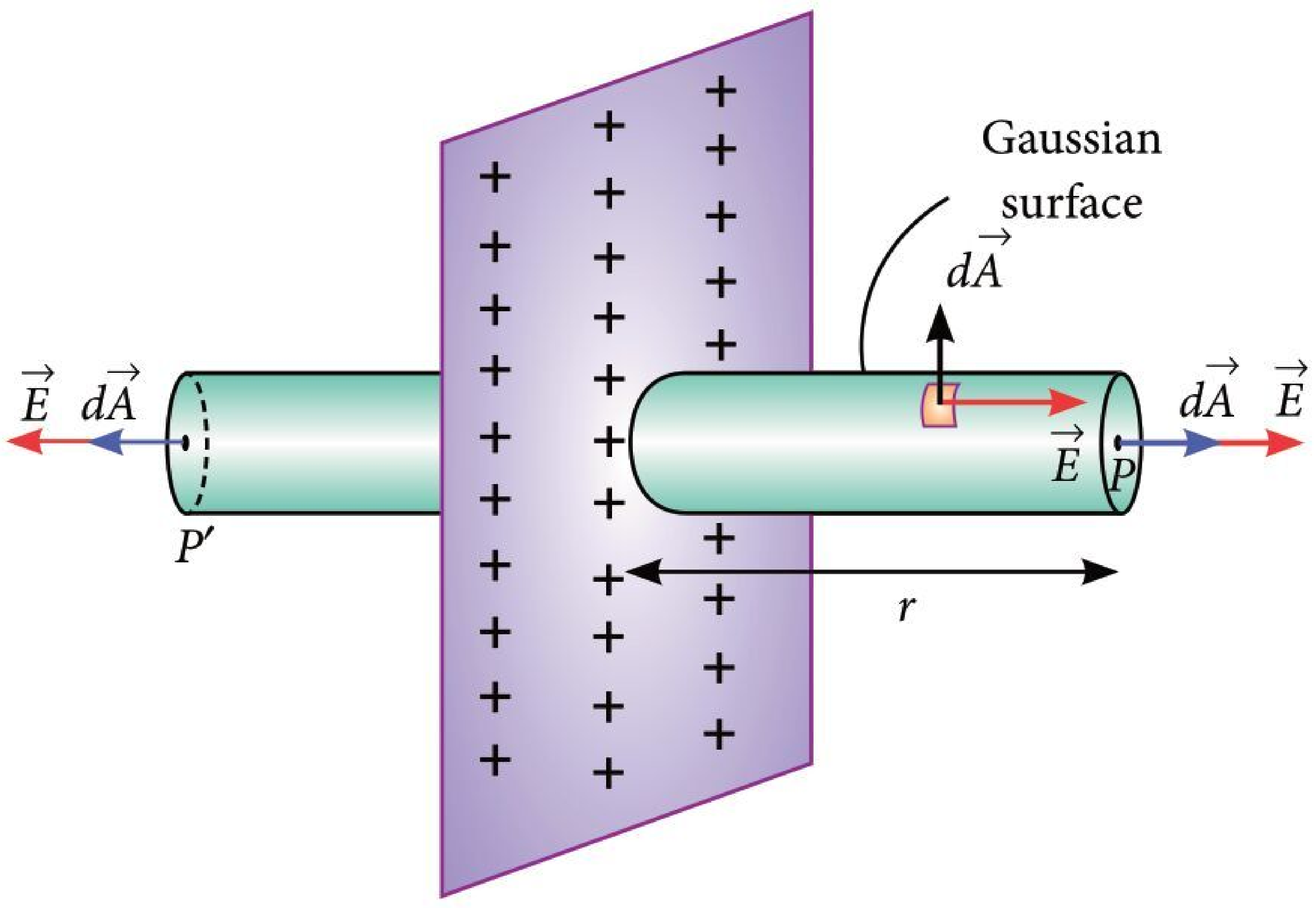
- Electric field lines of a positive point charge shows the line of force of isolated positive point charge. They are directed radially outwards because a small positive charge would be accelerated by the electric force in the outward direction as shown in figure (a). They extended to infinity.
- Field lines of negative point charge like that of a positive point charge, the electric field of a negative point charge is also spherically symmetric but the lines of force point radially inwards as shown in figure (b). They assumed to start from infinity.



(a) (b)

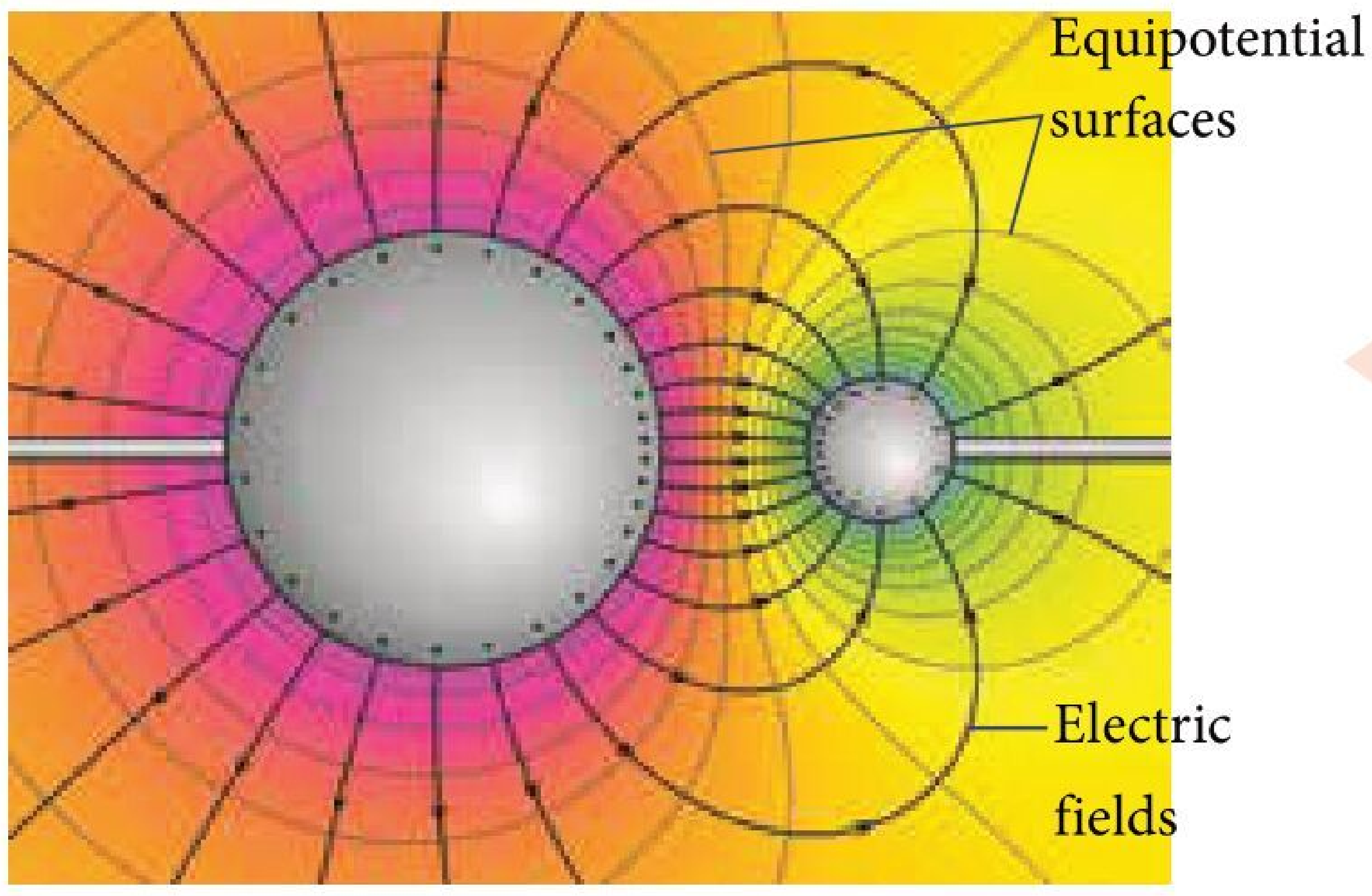
Applications of Gauss's Law

- As, area of the sheet intercepted by the cylinder is dA,therefore total charge enclosed by the cylinder = σdA.
- Electric field at point P due to infinite non-conducting charged sheet, $E = \frac{\sigma}{2\varepsilon_0}$
- Electric field due to conducting charged surface, $E = \frac{\sigma}{\varepsilon_0}$



Electric field due to a non-conducting sheet

02 | Electrostatic Potential and Capacitance



Equipotential Surfaces

- For a uniform electric field along x-direction, the equipotential surfaces are planes normal to the electric field *i.e.*, planes parallel to the y-z plane.
- As shown in figure, the electric fields are perpendicular to the equipotential surfaces.
- It is closer in regions of strong electric field and farther apart in the region of weak electric fields.

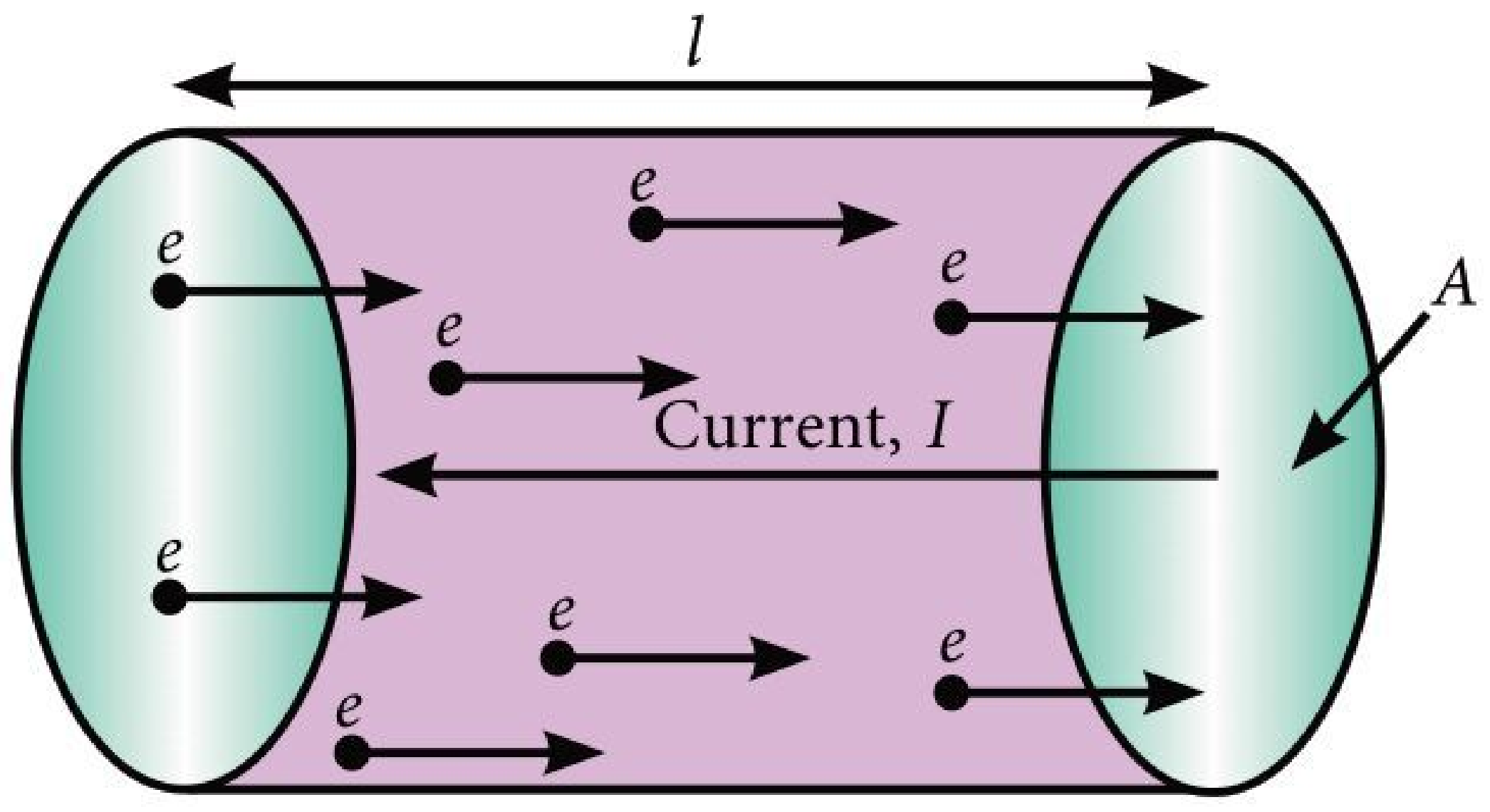
03 | Current Electricity

Drift of Electron

When a potential difference V is applied across a conductor of length l, the drift velocity in terms of V is $v_d = eV\tau/ml$. If the area of cross-section of the conductor is A and the number of electrons per unit volume or the electron density of the conductors is n, then, $v_d = \dfrac{I}{enA}$. Also, $I = enA \cdot \dfrac{eV\tau}{ml}$

From Ohm's law, V/I = constant = R

Then, $R = ml/ne^2\tau A$

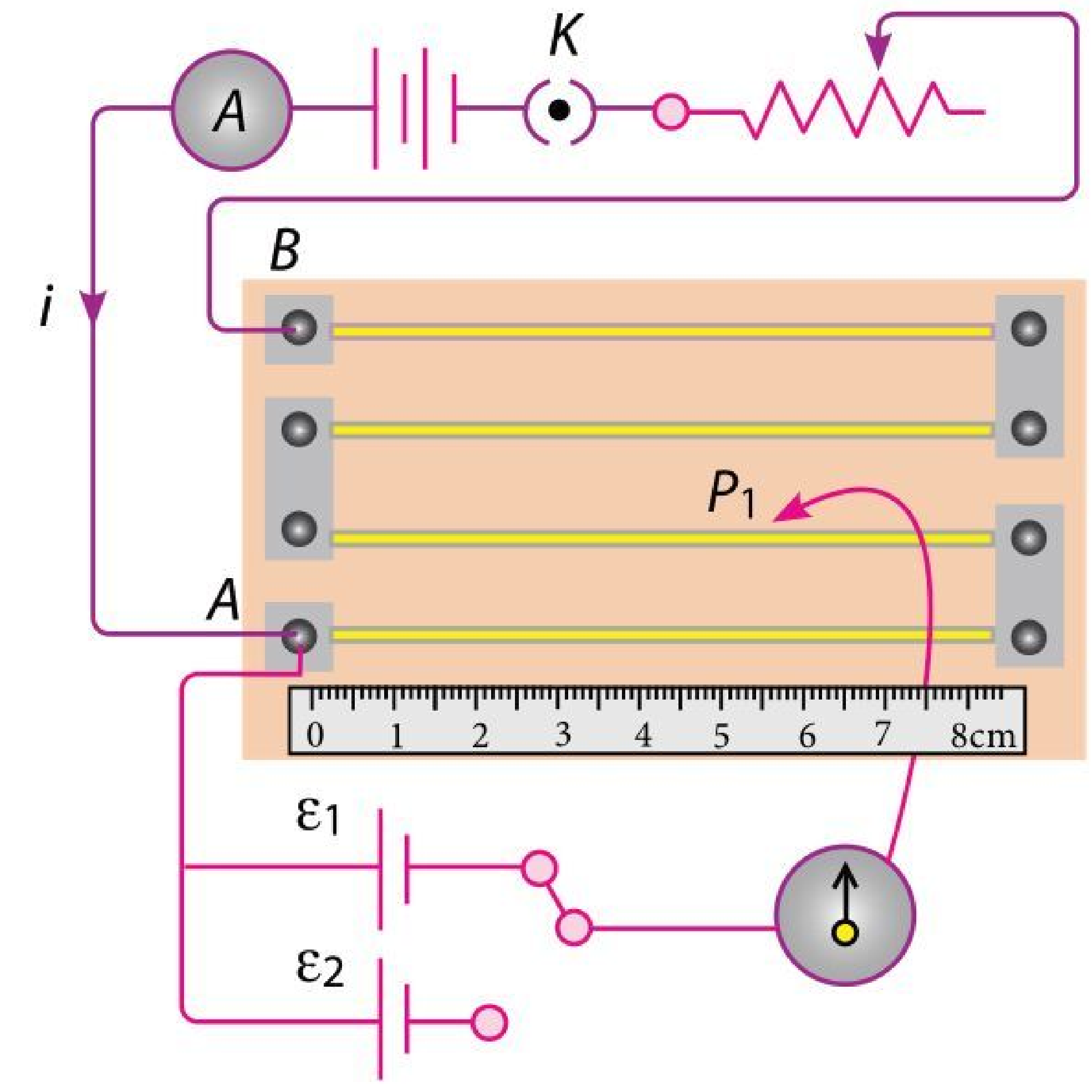


Potentiometer

- It is a device which is used as a voltage divider or variable resistor in a circuit.

- The principle of working of a potentiometer is that the fall of potential across any portion of the potentiometer wire is directly proportional to the length of that portion provided the wire should be of uniform area of cross-section and constant current should flow through the wire.

i.e., $V \propto l$ or $V = kl$; k = potential gradient



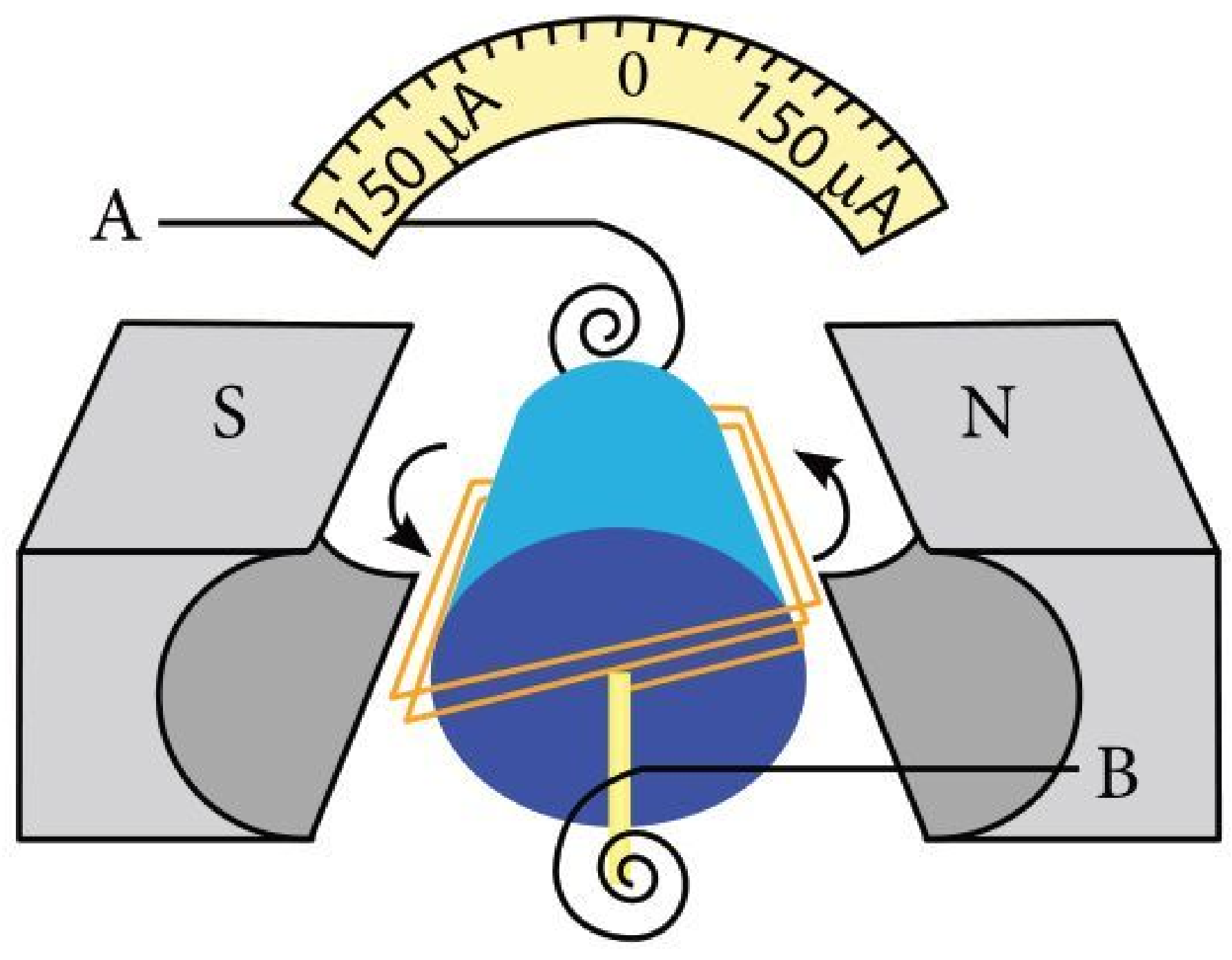
Also the measured internal resistance is given by

$$r = \left(\frac{l_1}{l_2} - 1\right)R$$

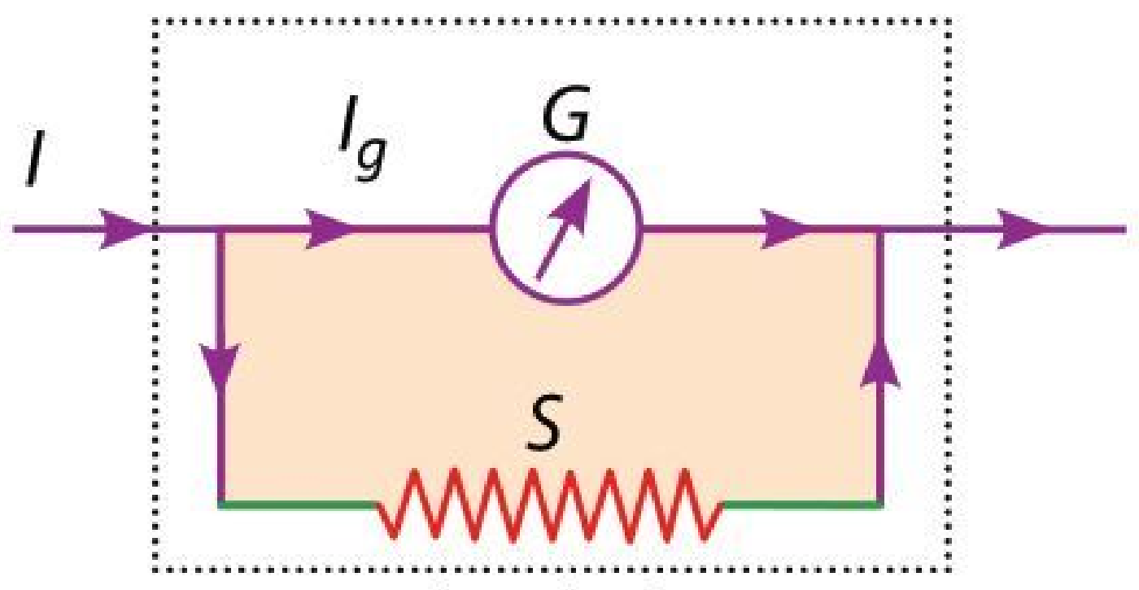
04 | Moving Charges and Magnetism

The Moving Coil Galvanometer

- In moving coil galvanometer, the current (I) passing through the galvanometer is directly proportional to its deflection (ϕ).
- We define the current sensitivity of the galvanometer as the deflection per unit current (ϕ/I).

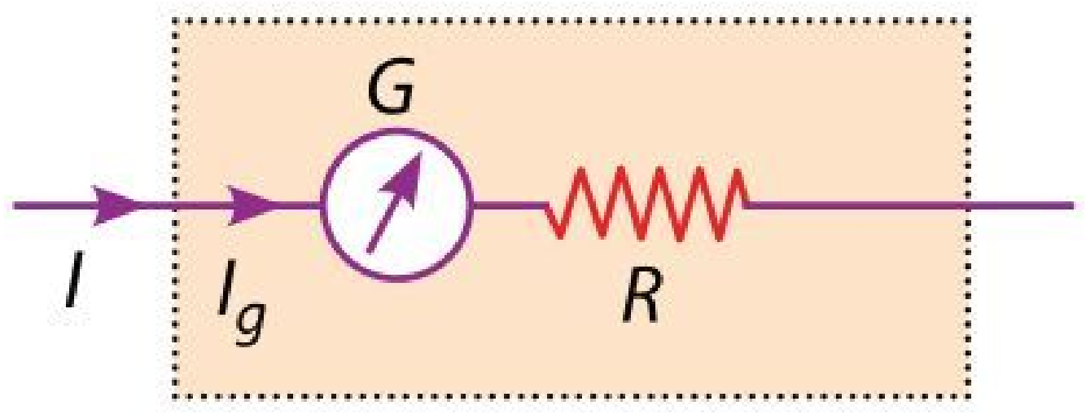

150 μA
0
150 μA
A
S
N
B

Moving Coil Galvanometer



$I_s = I - I_g$

Conversion of Galvanometer into Ammeter



Conversion of Galvanometer into Voltmeter

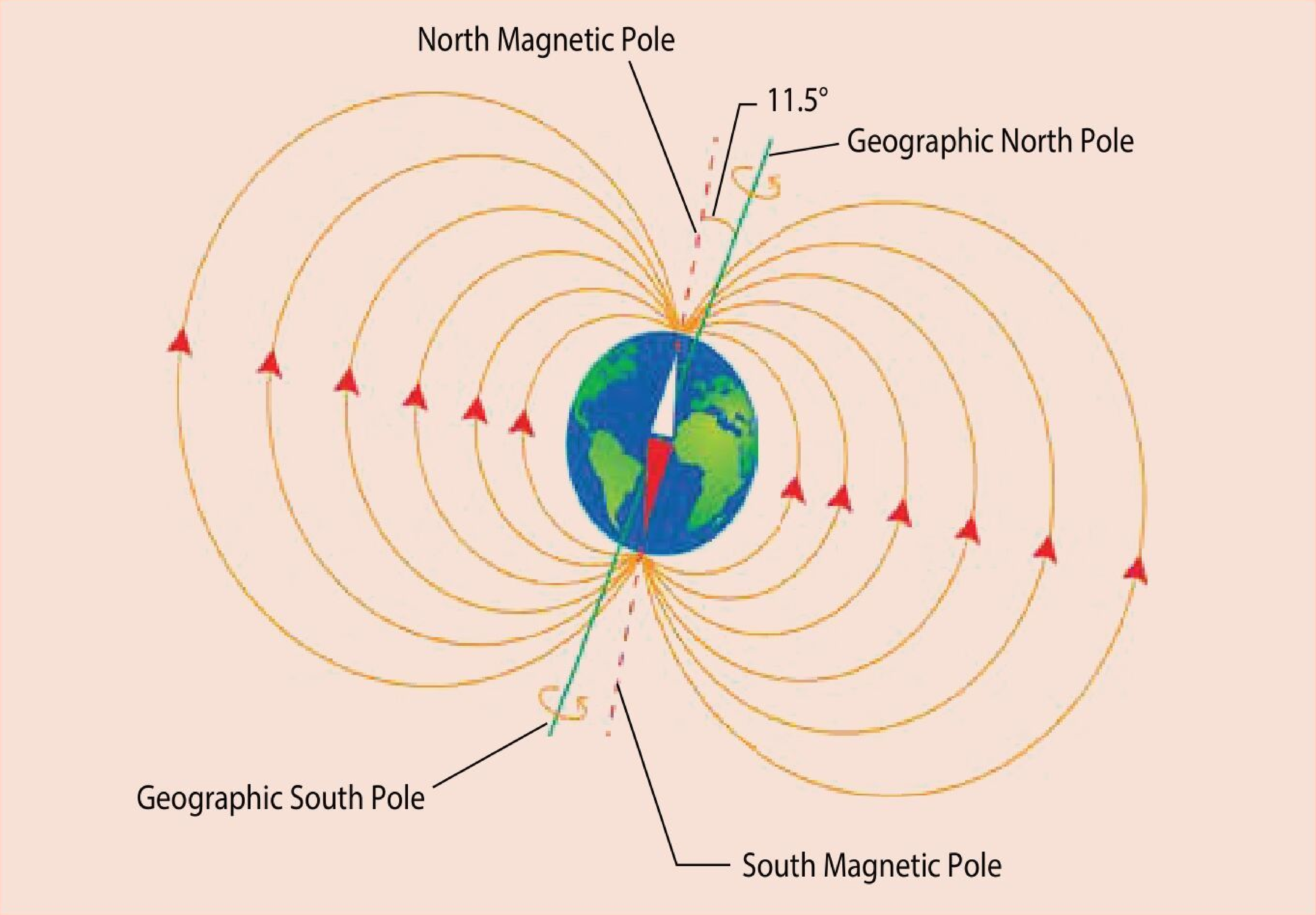
- We define the voltage sensitivity as the deflection per unit volt (ϕ/V) of applied potential difference.
- Galvanometer can be converted into an ammeter as well as voltmeter as shown in the figure.

05 | Magnetism and Matter

Earth's Magnetic Field

Given figure shows the Earth as a giant magnetic dipole

The magnetic north and south have been named after the direction of freely suspended magnetic needle and not after the poles of the imaginary magnet.


North Magnetic Pole
11.5°
Geographic North Pole
Geographic South Pole
South Magnetic Pole

mtG

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10 & 12
2023 EDITION

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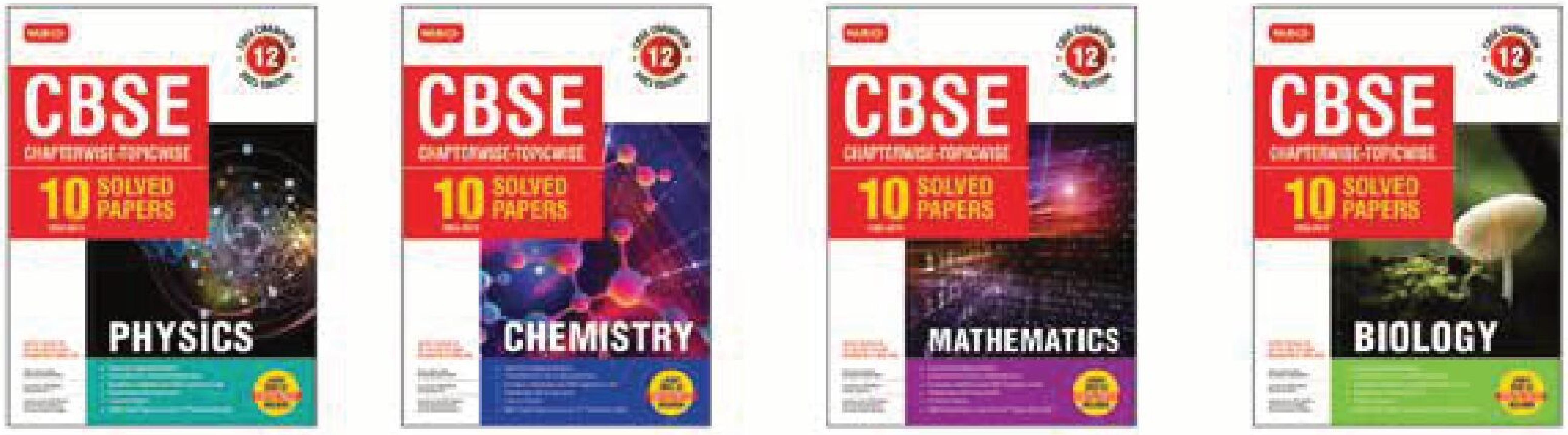
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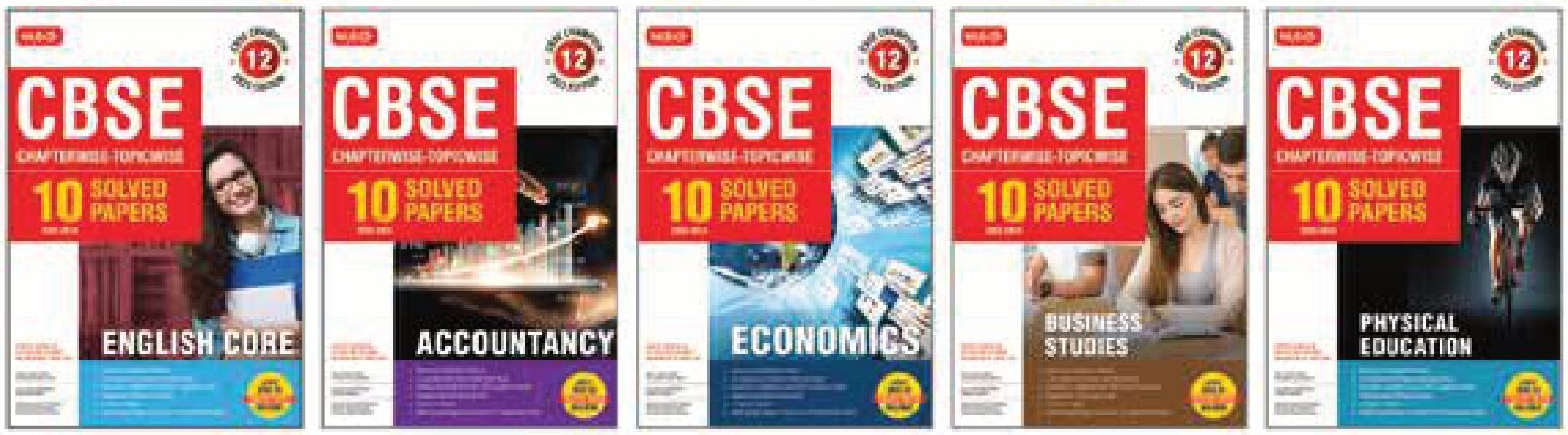
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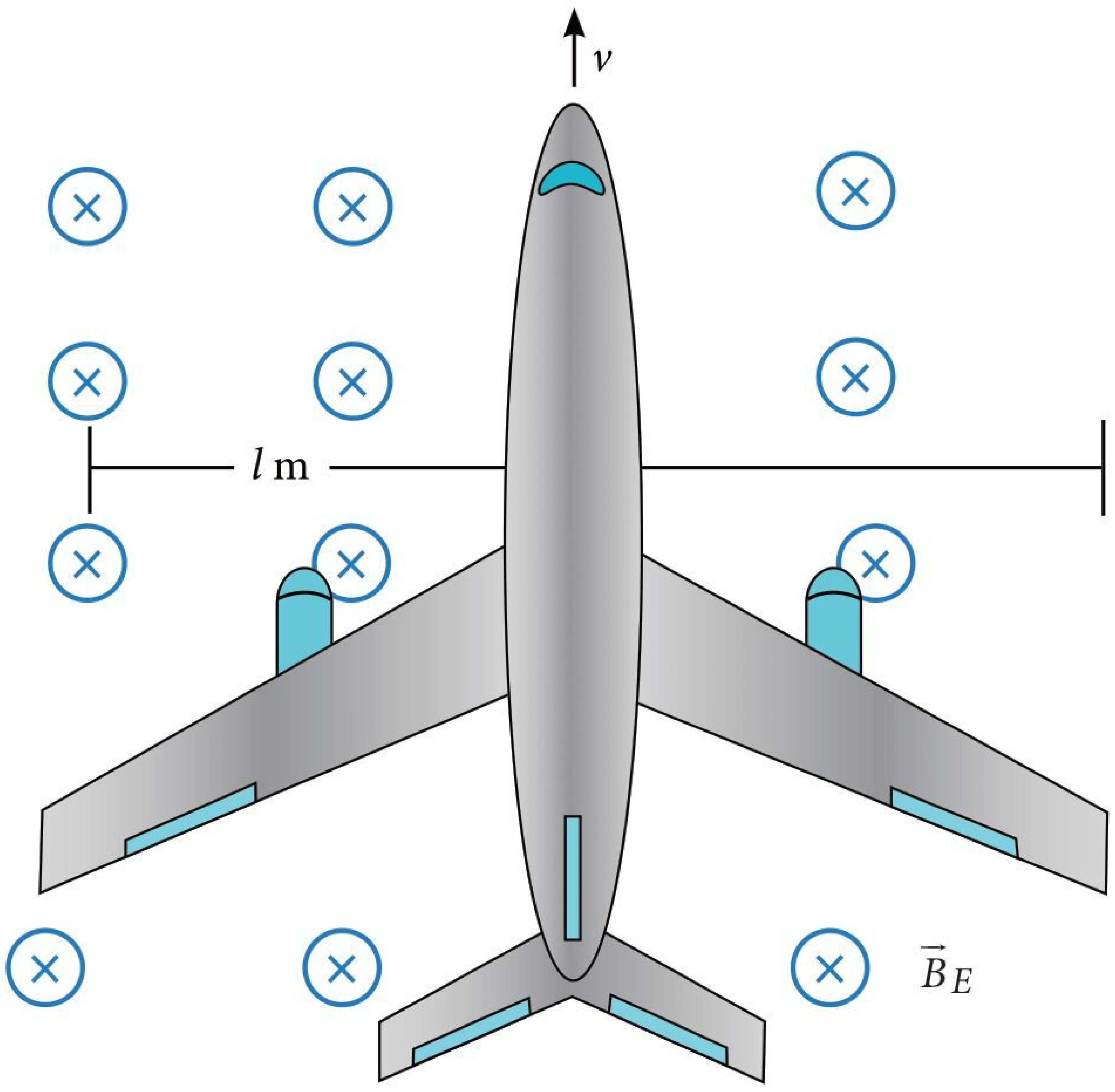
- Quick Recap with Brain Map
- Previous 10 years (2022- 2013) questions of CBSE
- CBSE Cognitive Level Tagging
- Key Points, Answer Tips, Concept Applied, Shortcuts, Alternating Methods, Commonly Made Mistakes provided
- CBSE Topper's Answers
- Past 3 years CBSE Sample Question Papers
- Chapterwise Self-Assessment
- 5 Practice Papers
- CBSE Sample Paper (Issued on 16th September 2022)

LATEST 2022-23 PRACTICE PAPERS INCLUDED

06 | Electromagnetic Induction

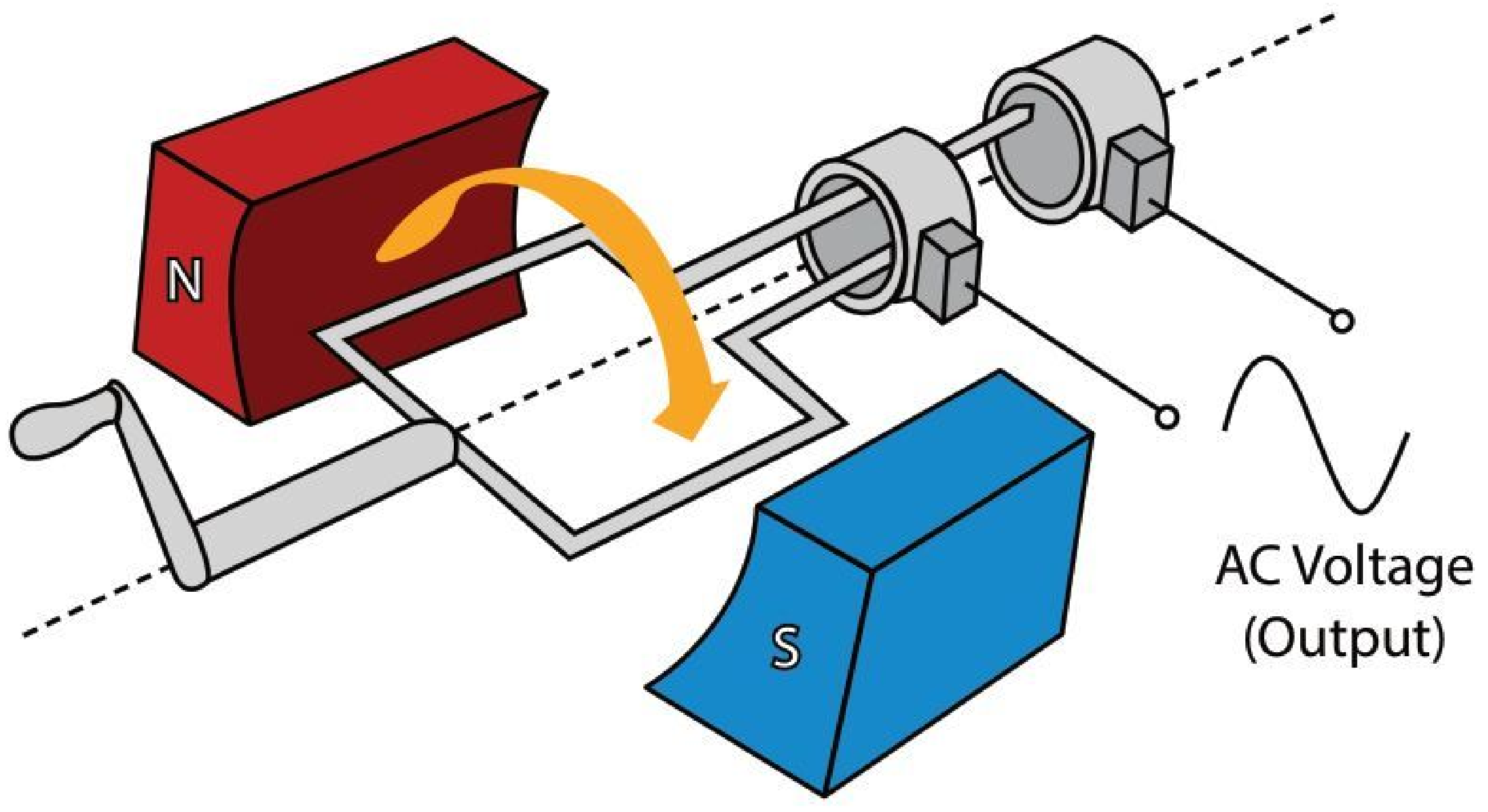
Motional Electromotive Force : Emf Across Wings of an Airplane

- Motional emf can be measured on airplanes.
  As the plane flies through the Earth's magnetic field as shown in figure $(\vec{B}_E)$, as emf is induced between the wing tips.
- Motional emf is largest when the direction of motion of the metallic rod is perpendicular to length of the rod and perpendicular to the magnetic field.
- It depend on magnetic field, velocity and length of the rod.

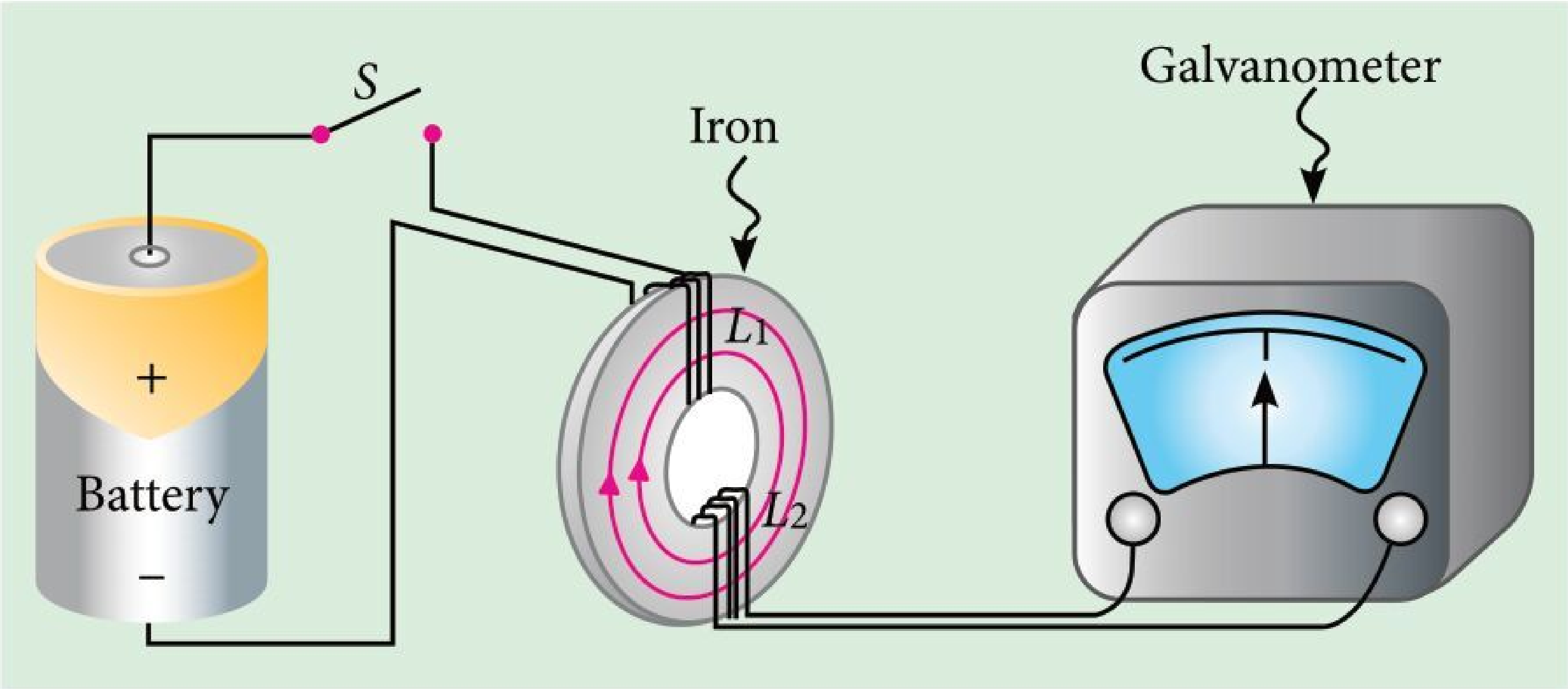


Generation of Alternating Current : AC Generator

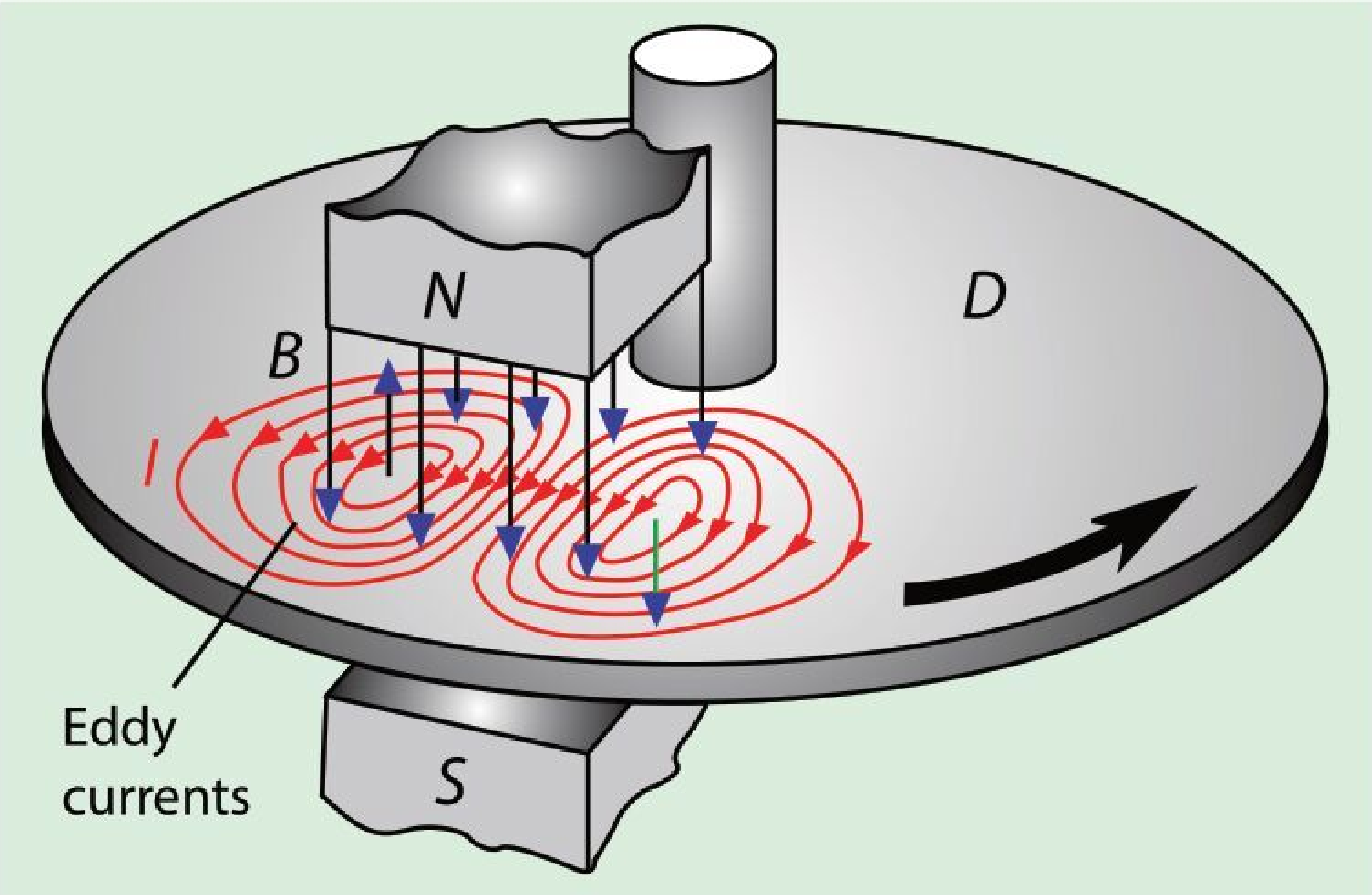
- **Principle and working of AC generator :** It is a device based on the phenomenon of electromagnetic induction. Whenever amount of magnetic flux linked with a coil changes, an emf is induced in the coil.
- **Change in magnetic flux :** When the switch S is closed, there is a change in magnetic flux associated with loop L_2, and hence current is induced which is indicated by the galvanometer.



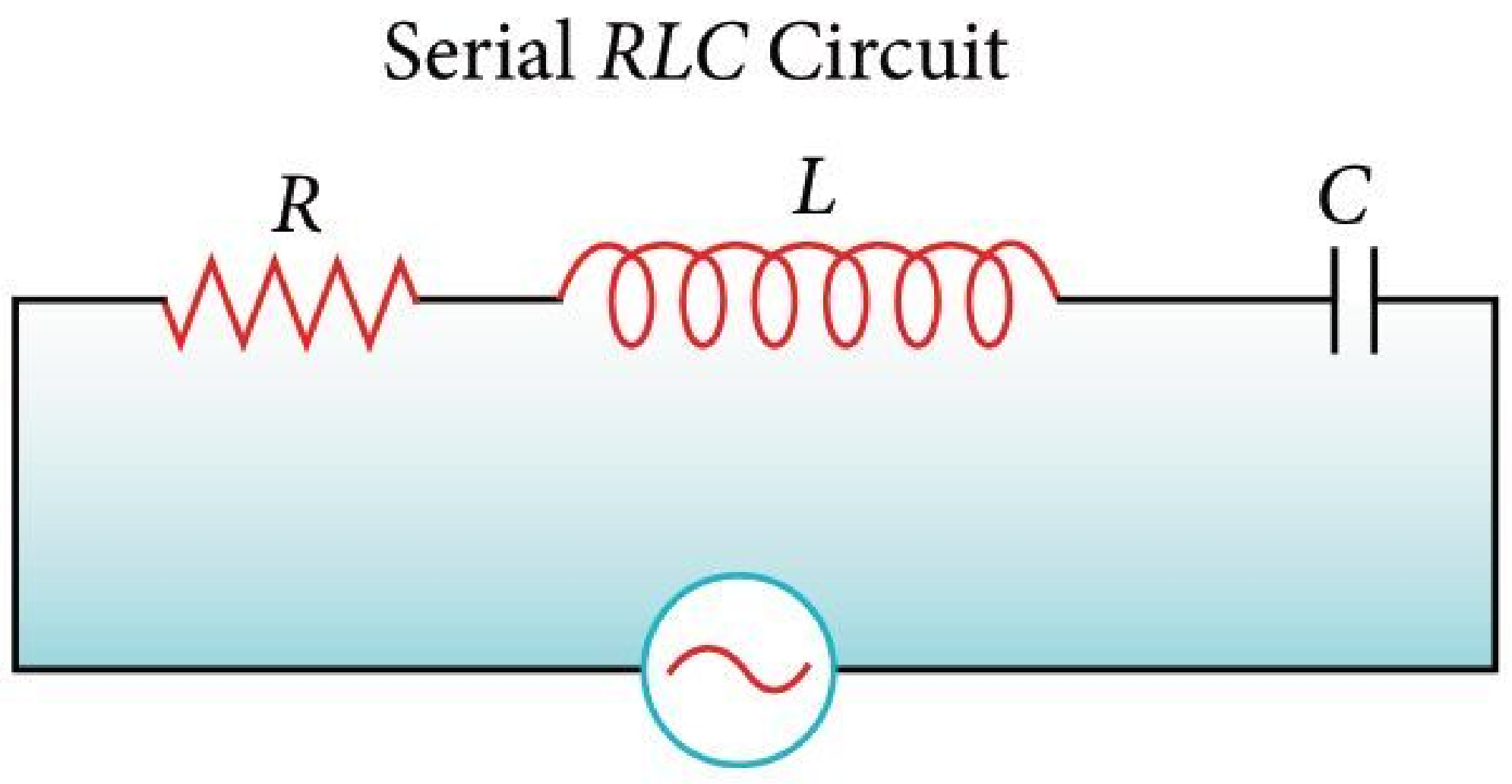
AC Generator

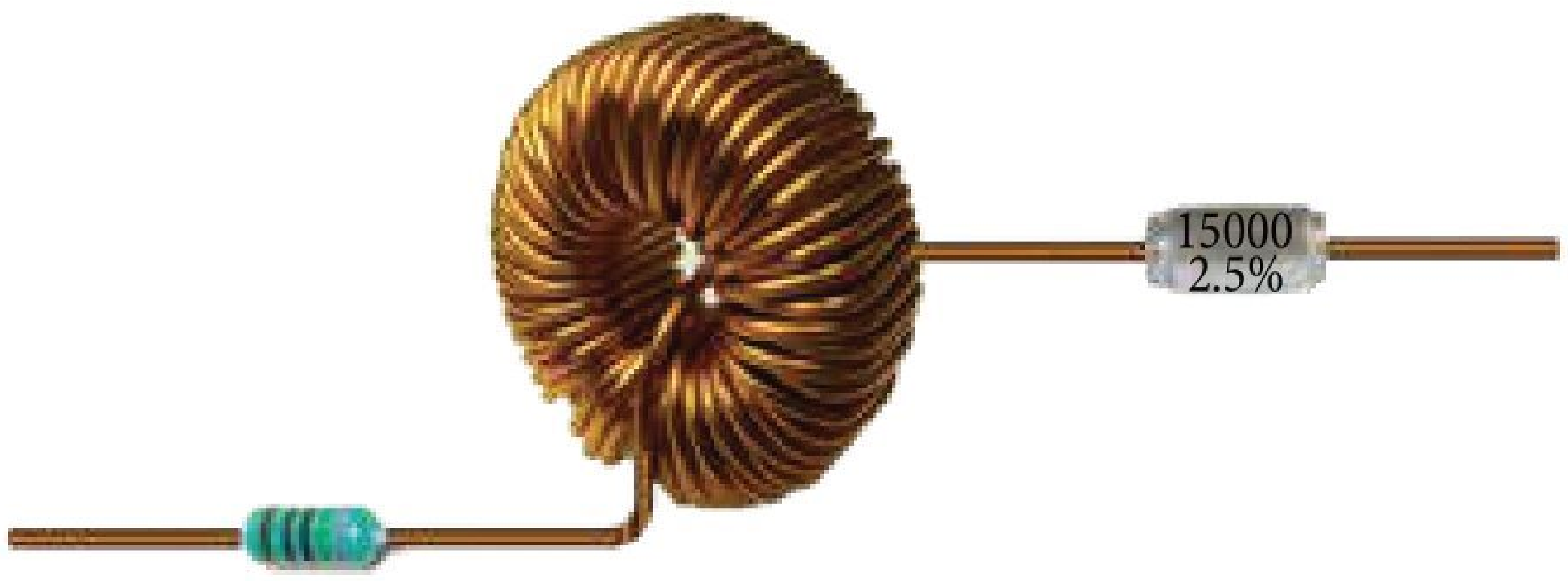


- When the disc (D) rotates, the magnetic flux associated with the surface of the disc changes and hence the eddy current is induced as shown in the figure.



07 | Alternating Current


Serial RLC Circuit
R
L
C



AC Voltage Applied to a Series *LCR* Circuit

- Suppose a resistance R, an inductance L and a capacitance C are connected in series to a source of alternating emf ε given by $\varepsilon = \varepsilon_0 \sin\omega t$.
- *LCR* circuits help in reducing too much power consumption by controlling the current flowing through an electronic device.

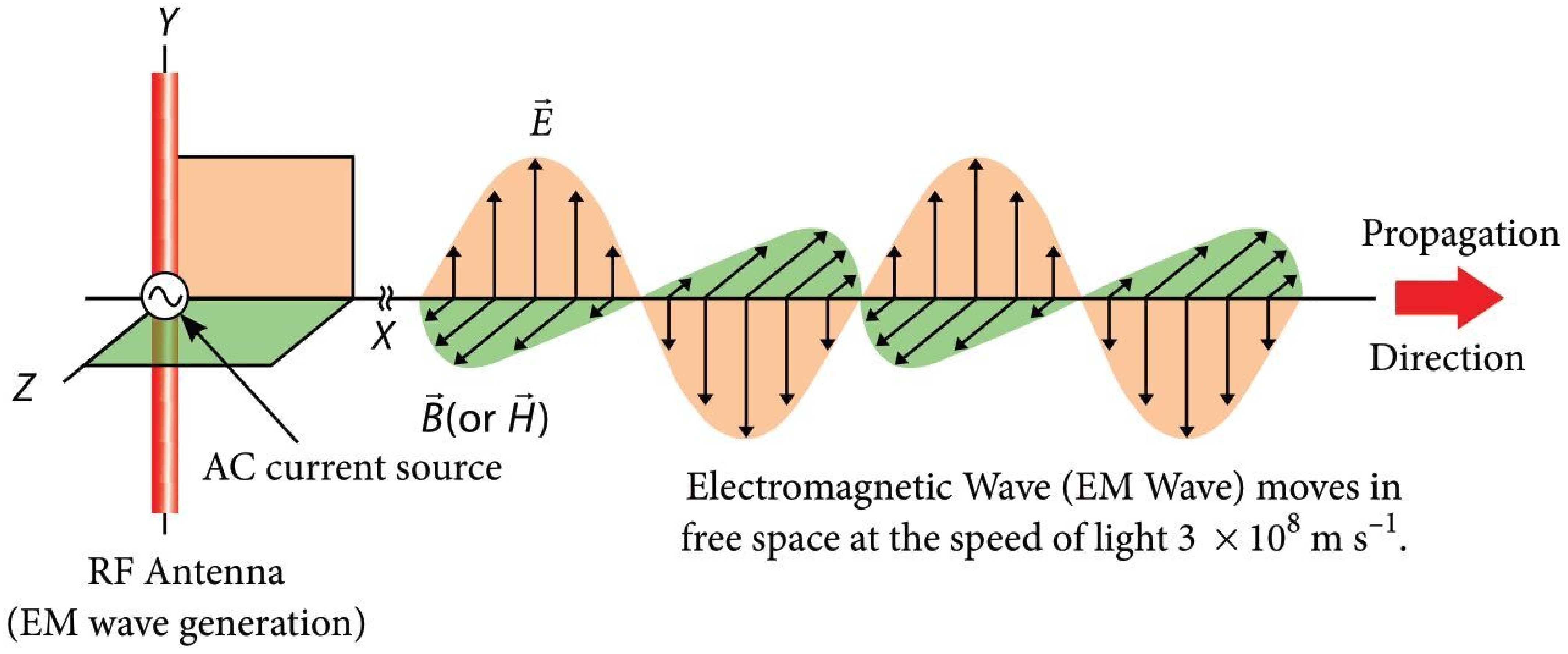
08 | Electromagnetic Waves

Production and Propagation of Electromagnetic Waves

- Electromagnetic waves are produced by oscillating charge or RF antenna.
- Direction of propagation of waves is given by

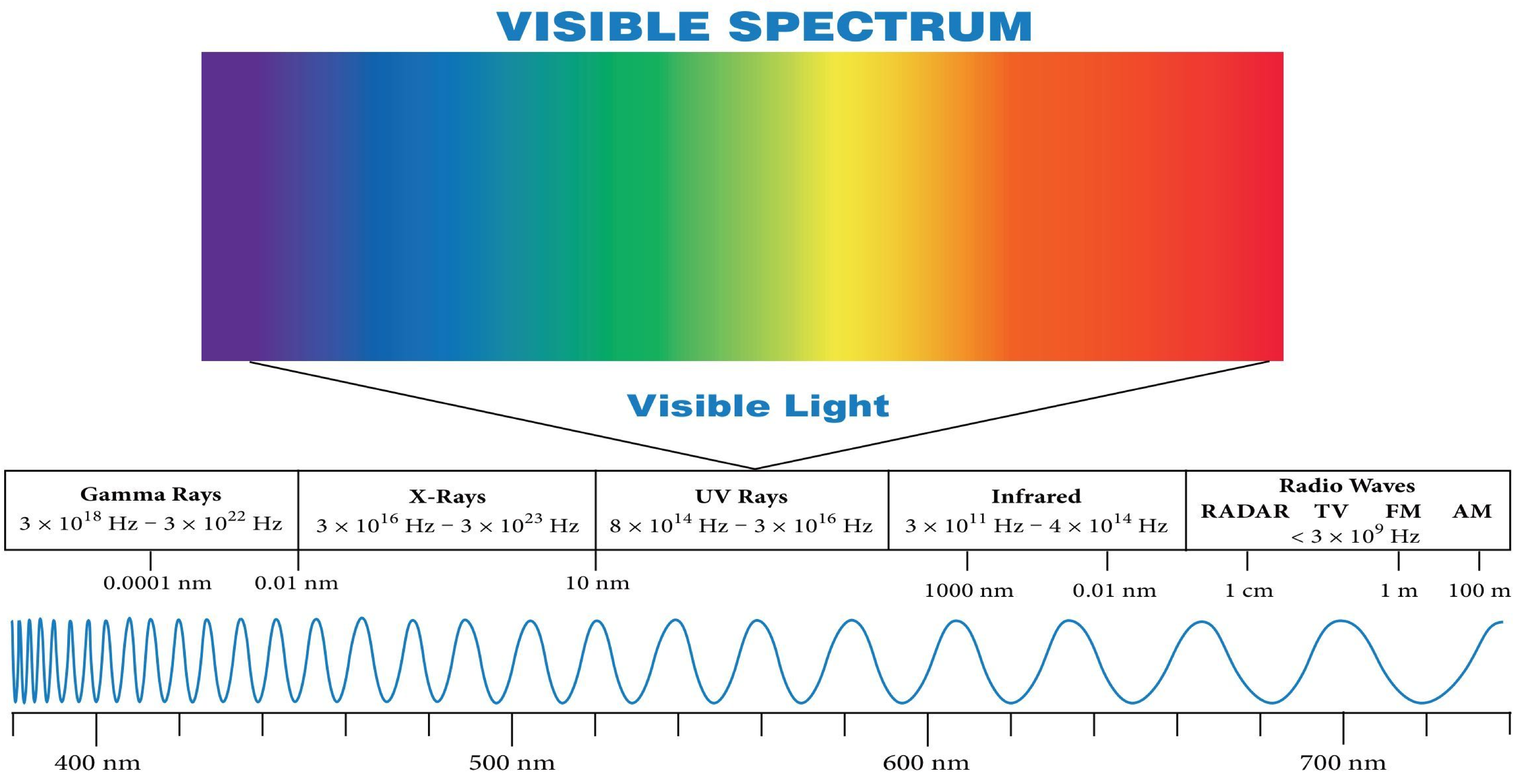
$$\hat{k} = \hat{E} \times \hat{H}$$

- In electromagnetic wave, the electric and magnetic fields are perpendicular to each other and to the direction of propagation.


Y
$\vec{E}$
Propagation
Direction
X
Z
$\vec{B}$(or $\vec{H}$)
AC current source
RF Antenna
(EM wave generation)
Electromagnetic Wave (EM Wave) moves in free space at the speed of light 3×10^8 m s^{-1}.

Electromagnetic Spectrum

- It is the orderly distribution of the em waves in accordance with their wavelength or frequency into distinct groups having widely differing properties as shown in the figure.


VISIBLE SPECTRUM
Visible Light
Gamma Rays
3×10^{18} Hz – 3×10^{22} Hz
X-Rays
3×10^{16} Hz – 3×10^{23} Hz
UV Rays
8×10^{14} Hz – 3×10^{16} Hz
Infrared
3×10^{11} Hz – 4×10^{14} Hz
Radio Waves
RADAR TV FM AM
$< 3 \times 10^{9}$ Hz
0.0001 nm
0.01 nm
10 nm
1000 nm
0.01 nm
1 cm
1 m
100 m
400 nm
500 nm
600 nm
700 nm

To be continued in next issue…

CLASS-XI

BRUSH UP for NEET/JEE

Brush up your concepts to get high rank in NEET/JEE (Main and Advanced) by reading this column. This specially designed column is updated year after year by a panel of highly qualified teaching experts well-tuned to the requirements of these Entrance Tests.

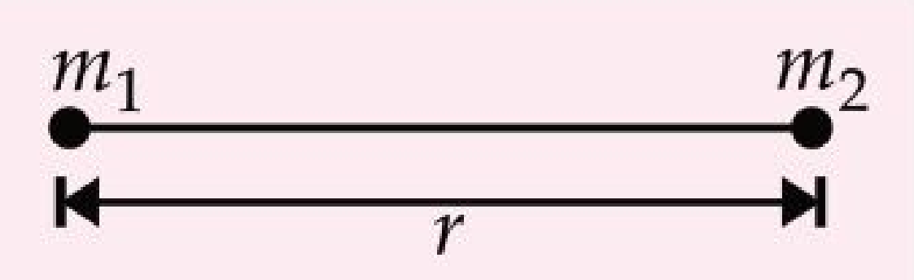
Unit 5 Gravitation

NEWTON'S LAW OF GRAVITATION

It states that every body in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. This force acts along the line joining the two bodies.

According to Newton's law of Gravitation,

$$F \propto \frac{m_1 m_2}{r^2} \quad \text{or} \quad F = \frac{G m_1 m_2}{r^2}$$



where G is a constant of proportionality and is called universal gravitational constant.

- Universal gravitational constant G is a scalar quantity.
- Its value is same throughout the universe and is independent of the nature and size of the bodies as well as the nature of the medium between the bodies.
  - Value of G in SI system is 6.67×10^{-11} N m^2 kg^{-2} and in CGS system is 6.67×10^{-8} dyne cm^2 g^{-2}.
  - Dimensional formula for G is $[M^{-1}L^3T^{-2}]$.

Gravitational Force

The law of gravitation is universal as it is applicable to all bodies, independent of nature of the intervening medium, temperature and other physical condition of the bodies.

- It forms action-reaction pair, *i.e.*, the gravitational forces between two bodies are equal in magnitude but opposite in direction and hence they obey Newton's third law of motion.
- It is a conservative force, *i.e.* work done by it is path independent.
- It is a central force, *i.e.*, it acts along the line joining the centre of the two interacting bodies.

ACCELERATION DUE TO GRAVITY

Acceleration produced in a body due to the force of gravity is called as acceleration due to gravity. It is denoted by symbol 'g' and mathematically it is given by

$$g = \frac{GM_e}{r^2}$$

where M_e is the mass of the earth and r is the distance of the body from the centre of the earth.

- If the body is on the surface of the earth, *i.e.*, $r = R_e$ (radius of the earth), then $g = \frac{GM_e}{R_e^2}$
- It is also defined as the acceleration produced in the body while falling freely under the effect of gravity alone.
- It is a vector quantity. Its SI unit is m s^{-2} and its dimensional formula is $[M^0LT^{-2}]$.
- The value of g on the surface of earth is taken to be 9.8 m s^{-2}.
- The value of g varies with altitude, depth, shape and the rotation of earth.
- The acceleration due to gravity (g) is related with gravitational constant (G) by the relation

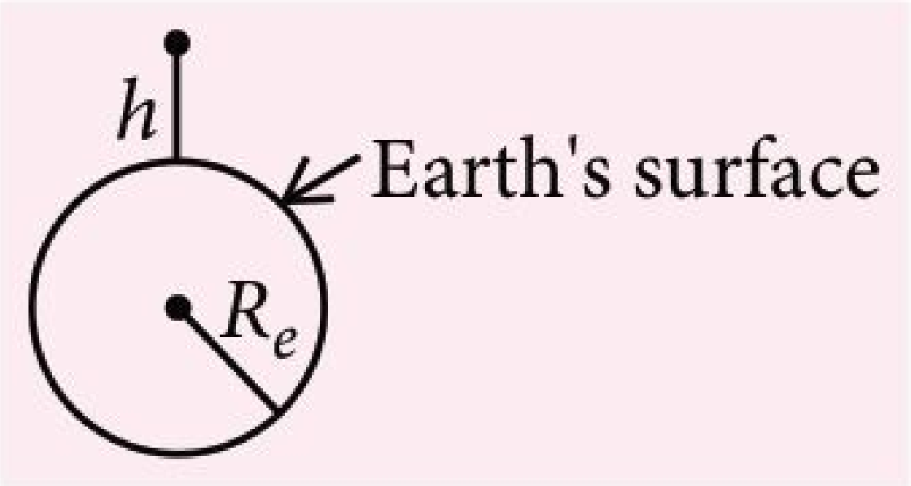
  $$g = \frac{GM_e}{R_e^2} = \frac{G\frac{4}{3}\pi R_e^3 \rho}{R_e^2} = \frac{4}{3}\pi G R_e \rho$$

  where M_e is the mass of the earth, R_e is the radius of the earth and ρ is the uniform density of the material of the earth.
- The value of acceleration due to gravity is independent of the shape, size, mass etc., of the body but depends upon mass and radius of the earth or planet due to which there is a gravity pull.

- If the radius of a planet decreases by $n\%$, keeping its mass unchanged, the acceleration due to gravity on its surface increases by $2n\%$.
- If the mass of a planet increases by $n\%$, keeping its radius unchanged, the acceleration due to gravity on its surface increases by $n\%$.
- If the density of a planet decreases by $n\%$, keeping its radius unchanged, the acceleration due to gravity decreases by $n\%$.

Variation of Acceleration due to Gravity

- **Due to altitude (h)**



  The acceleration due to gravity at height h above the earth's surface is given by

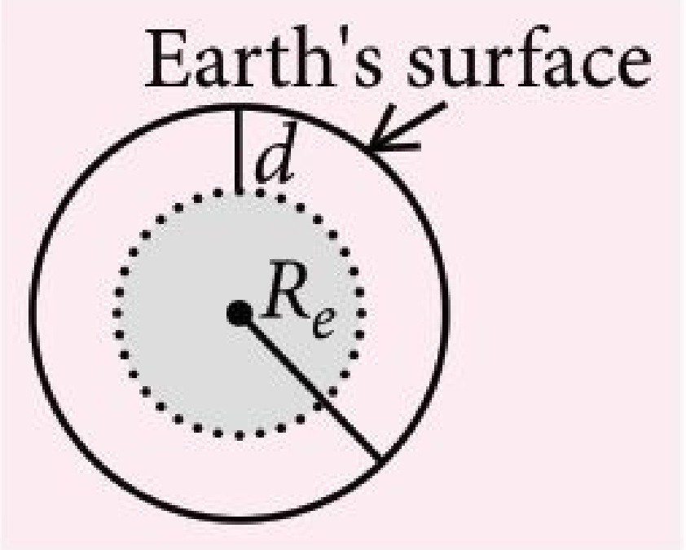
$$g_h = \frac{GM_e}{(R_e + h)^2} = g\left(1 + \frac{h}{R_e}\right)^{-2} \quad \left(\because g = \frac{GM_e}{R_e^2}\right)$$

  For $h << R_e$,

$$\therefore \quad g_h = g\left(1 - \frac{2h}{R_e}\right)$$

  When we move above the earth's surface, the value of acceleration due to gravity goes on decreasing.

- **Due to depth (d)**

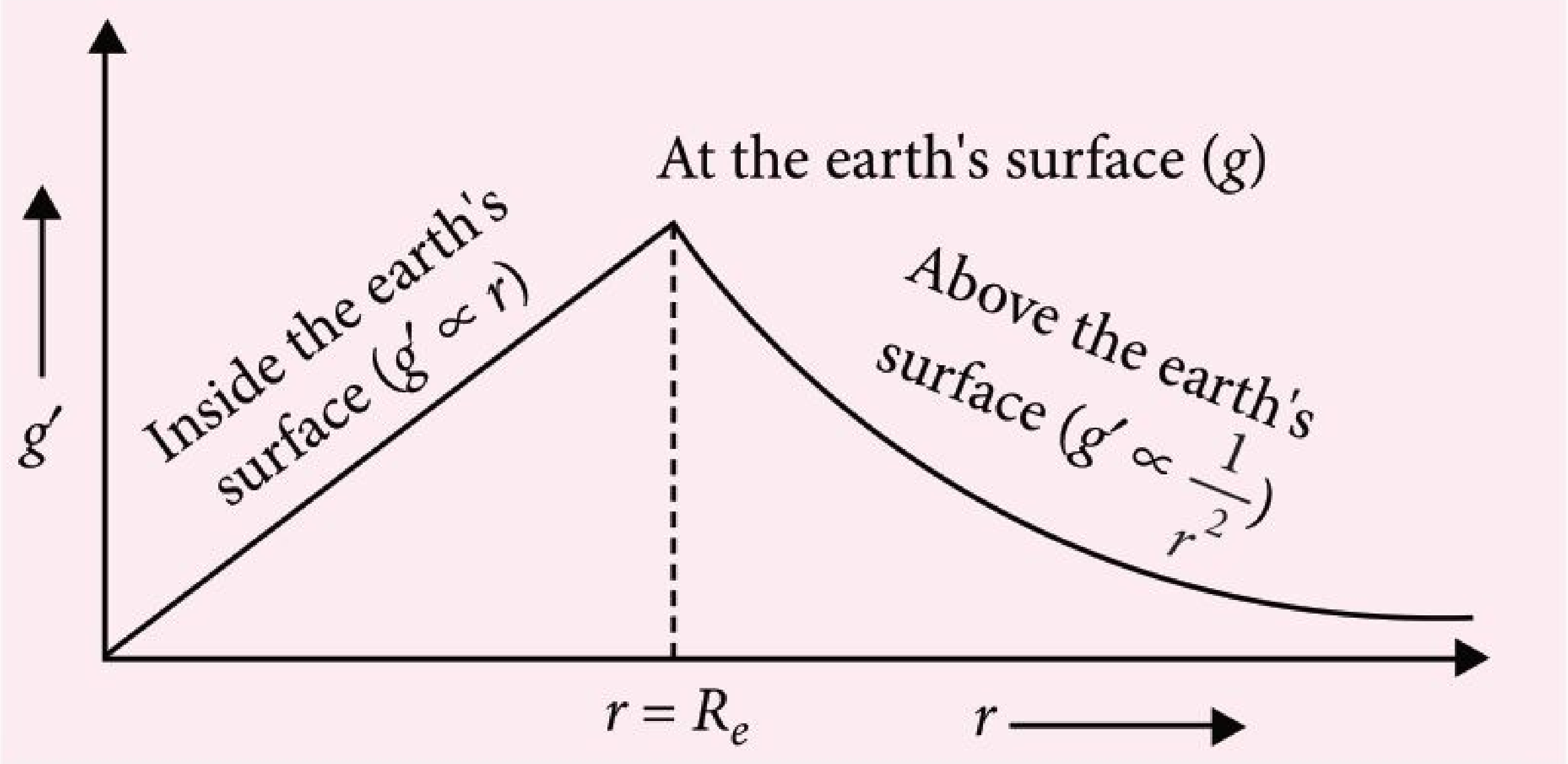


  The acceleration due to gravity at a depth d below the earth's surface is given by

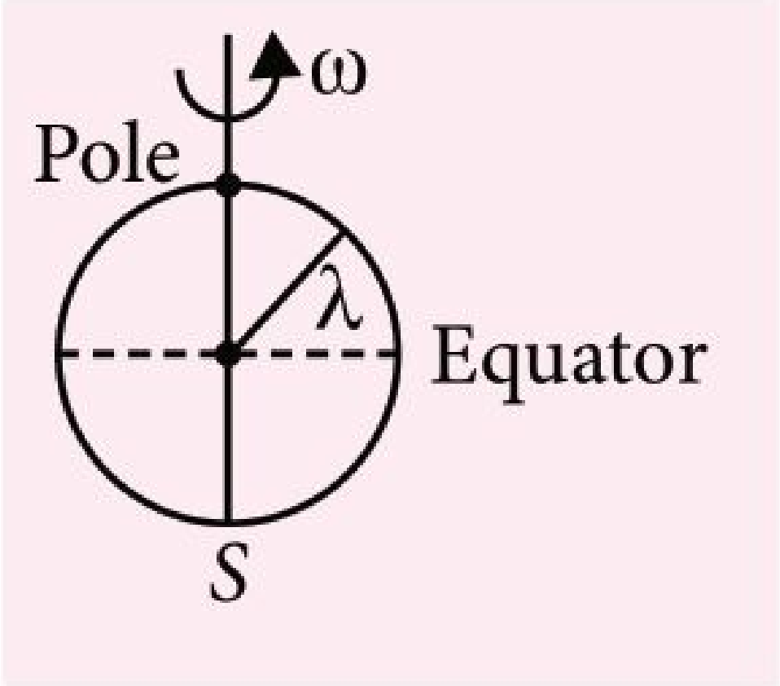
$$g_d = \frac{GM_e}{R_e^3}(R_e - d) = g\left(\frac{R_e - d}{R_e}\right) = g\left(1 - \frac{d}{R_e}\right)$$

  At the centre of the earth, $d = R_e$. $\therefore \quad g_d = 0$.

  - When we move below the earth's surface, the value of acceleration due to gravity also decreases. The value of acceleration due to gravity is maximum at the earth's surface and becomes zero at the centre of the earth.
  - The variation of acceleration due to gravity (g') with distance from the centre of the earth (r) is as shown in the figure.



- **Due to rotation of the earth about its axis**



  The acceleration due to gravity at latitude λ is given by $g_\lambda = g - R_e\,\omega^2\cos^2\lambda$

  where ω is the angular speed of rotation of the earth about its axis and its value is 7.3×10^{-5} rad s^{-1}.

  - At the equator, $\lambda = 0°$

    $g_\lambda = g_e = g - R_e\omega^2\cos^2 0° = g - R_e\omega^2$.
  - At the poles, $\lambda = 90°$

    $g_\lambda = g_p = g - R_e\omega^2\cos^2 90° = g$
  - The value of acceleration due to gravity increases from equator to the pole due to rotation of the earth.

    $g_p - g_e = g - (g - R_e\omega^2) = R_e\omega^2$
  - If the earth stops rotating about its axis ($\omega = 0$), the value of g will increase everywhere, except at the poles. On the contrary, if there is increase in the angular speed of the earth, then except at the poles the value of g will decrease at all places.

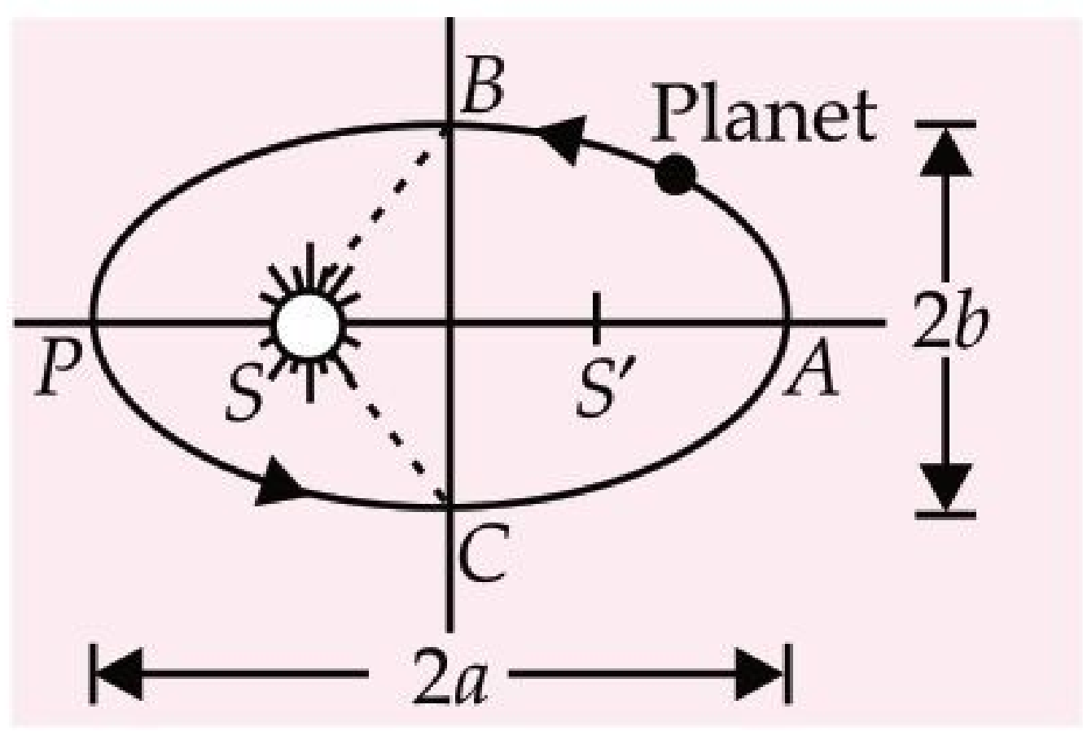
- **Due to shape of the earth**

  Earth is not a perfect sphere but it is an ellipsoid. The earth's radius is 21 km larger at the equator than at the poles. Thus, the earth has an equatorial bulge and is flattened at the poles. Both, rotation and equatorial bulge contribute additively to keep the g smaller at the equator than at the poles.

KEPLER'S LAWS OF PLANETARY MOTION

To explain the motion of the planets, Kepler formulated the following three laws:

Law of Orbits (First Law)



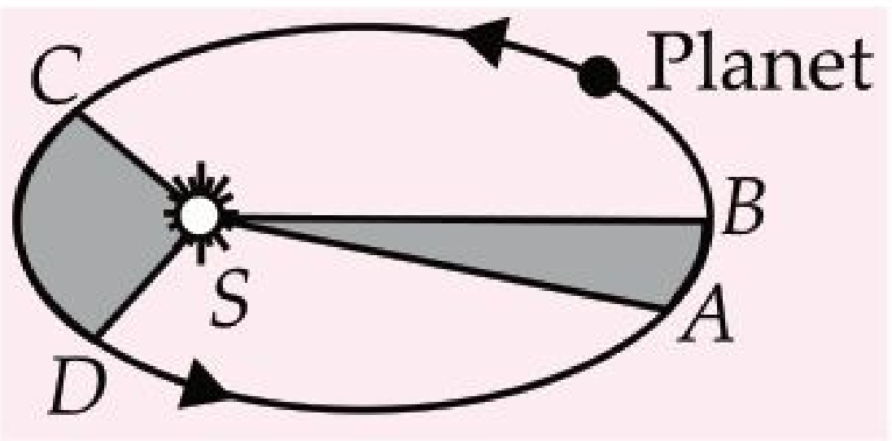
Each planet revolves around the sun in an elliptical orbit with the sun situated at one of the two foci.

As shown in figure, the planets move around the sun in an elliptical orbit. An ellipse has two foci S and S' the sun remains at one of the line foci.

The points P and A on the orbit are called the perihelion and the aphelion and represent the closest and farthest distances from the sun respectively.

Law of areas (Second Law)

The radius vector drawn from the sun to the planet sweeps out equal areas in equal intervals of time *i.e.*, the areal velocity of the planet (or the area swept out by the planet per unit time) around the sun is constant *i.e.*, areal velocity $= \frac{d\vec{A}}{dt} =$ a constant, for a planet.



Kepler's second law follows from the law of conservation of angular momentum.

Suppose a planet takes same time to go from position *A* to *B* as in going from *C* to *D*. From Kepler's second law, the areas *ASB* and *CSD* (covered in equal time) must be equal.

Law of periods (Third law)

The square of the time period of revolution of a planet around the sun is directly proportional to the cube of semi major axis of the elliptical orbit.

i.e., $T^2 \propto a^3$ [where *a* is the semi major axis of the elliptical orbit of the planet around the sun.]

This law is also known as harmonic law.

GRAVITATIONAL FIELD

- The space around a material body in which its gravitational pull can be experienced is called its gravitational field.
- The intensity of gravitational field (*E*) at a point due to a body of mass *M* at a distance *r* from the centre of body is

  $E = \frac{GM}{r^2}$ = acceleration due to gravity.
- The intensity of gravitational field is a vector quantity. It is always directed towards the centre of the mass producing the gravitational field.
- The value of intensity of gravitational field is zero at infinity.
- The total intensity of gravitational field at a point is the vector sum of the intensities of the gravitational fields due to individual mass bodies present in that field, *i.e.*, $\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$

GRAVITATIONAL POTENTIAL

The amount of work done in bringing a body having unit mass from infinity to a point without acceleration in the gravitational field.

- Gravitational potential at a point in the gravitational field due to a body of mass *M* at a distance *r* is given by $V = -\frac{GM}{r}$
- Gravitational potential *V* is a scalar quantity but potential gradient (dV/dr) is a vector quantity.
- Gravitational potential *V* is related with gravitational intensity *I* by the relation,

  $E = -dV/dr$
- In a gravitational field due to number of mass bodies, the total gravitational potential at a point is the sum of the gravitational potential due to individual mass bodies at that point, *i.e.*,

  $V = V_1 + V_2 + V_3 + \ldots\ldots\ldots\ldots$

GRAVITATIONAL POTENTIAL ENERGY

Gravitational potential energy of a body at a point in gravitational field of another body is equal to the amount of work done in bringing the given body from infinity to that point without acceleration.

- The gravitational potential energy of a body of mass *m* placed at a distance *r* from the centre of mass *M* is

  U = gravitational potential × mass of body

  $= -\frac{GM}{r} \times m$
- Work done against the gravitational force in taking a body of mass *m* from surface of earth to a height *h* is the change in potential energy of the body and is given by $W = \Delta U = \frac{GM\,mh}{R(R+h)}$

  (a) If $h << R$, then $dU = \frac{GM\,mh}{R^2} = gmh$

  (b) If $h = R$, then $dU = \frac{GM\,mh}{2R^2} = \frac{1}{2}gmh$
- Gravitational potential energy is a scalar quantity.

ESCAPE VELOCITY

The escape speed on the earth (or any planet) is defined as the minimum speed with which a body has to be projected vertically upwards from the surface of earth (or any other planet) so that it just crosses the gravitational field of earth (or of that planet) and never returns on its own.

Escape speed v_e is given by

$$v_e = \sqrt{\frac{2GM}{R}} \quad \left(\begin{array}{r}\text{where } M = \text{Mass of the earth or planet}\\ R = \text{Radius of the earth or planet}\end{array}\right)$$

$$v_e = \sqrt{\frac{2G \times \text{volume} \times \text{density}}{R}}$$

or $$v_e = \sqrt{\frac{2G}{R} \times \frac{4}{3}\pi R^3 \rho} = \sqrt{\frac{8\pi\rho G R^2}{3}}$$

- For earth, $v_e = 11.2$ km s^{-1}

SATELLITE

Consider a satellite of mass m revolving in a circle around the earth. If the satellite is at a height h above the earth's surface, the radius of its orbit is $r = R + h$, where R is the radius of the earth. The gravitational force between m and M provides the necessary centripetal force for circular motion.

Orbital Velocity (v_0)

The minimum speed required to put the satellite into a given orbit around the earth is called the orbital speed of a satellite.

- Orbital velocity is independent of the mass of the orbiting body and is always along the tangent to the orbital.

  Close to the surface of the earth, $r = R$ as $h = 0$

  $$\therefore \quad v_0 = \sqrt{\frac{GM}{R}} = \sqrt{gR} = \sqrt{10 \times 6.4 \times 10^6} \approx 8 \text{ km s}^{-1}$$

  Close to the surface of the planet,

  $$v_0 = \sqrt{\frac{GM}{R}} = \frac{v_e}{\sqrt{2}}, \text{ i.e., } v_e = \sqrt{2}v_0$$

- Orbital velocity vary near the surface of the earth and is about 7.92 km s^{-1}.
- If the altitude of the satellite is n times the radius of the earth, then the orbital velocity will be $\left(1/\sqrt{1+n}\right)$ times the orbital velocity near the surface of the earth.
- If the radius of the orbit of a satellite is n times the radius of the earth, then its orbital velocity will be $\left(1/\sqrt{n}\right)$ the orbital velocity near the surface of the earth.

Time Period of a Satellite

The time taken by a satellite to complete one revolution is called the time period (T) of the satellite.

It is given by, $T = \frac{2\pi r}{v} = 2\pi r\sqrt{\frac{r}{GM}}$

or, $T = \frac{2\pi r\sqrt{r}}{\sqrt{GM}}$ or, $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3 \quad \Rightarrow \quad T^2 \propto r^3$

Angular Momentum of a Satellite (*L*)

In case of satellite motion, angular momentum will be given by

$$L = mvr = mr\sqrt{\frac{GM}{r}}, \; L = (m^2GMr)^{1/2}$$

In case of satellite motion, the net force on the satellite is centripetal force. The torque of this force about the centre of the orbit is zero. Hence, angular momentum of the satellite is conserved, *i.e.*, L = constant.

Energy of a Satellite

The PE of a satellite is

$$U = mV = -\frac{GMm}{r} \qquad \left[\because V = -\frac{Gm}{r}\right]$$

The kinetic energy of the satellite is

$$K = \frac{1}{2}mv_0^2 = \frac{GMm}{2r} \qquad \left[\because v_0 = \sqrt{\frac{GM}{r}}\right]$$

Total mechanical energy of the satellite

$$= -\frac{GMm}{r} + \frac{GMm}{2r} = -\frac{GMm}{2r}$$

Total energy of a satellite in its orbit is negative. Negative energy means that the satellite is bound to the central body by an attractive force and energy must be supplied to remove it from the orbit to infinity.

Binding Energy of the Satellite

The energy required to remove the satellite from its orbit to infinity is called binding energy of the satellite.

$$\text{Binding energy} = -E = \frac{GMm}{2r}$$

Types of Satellites

Geostationary satellite

If there is a satellite rotating in the direction of earth's rotation, *i.e.*, from west to east, then for an observer on the earth, the relative angular velocity of the satellite will be ($\omega_S - \omega_E$).

However, if $\omega_S - \omega_E = 0$, satellite will appear stationary relative to the earth. Such a satellite is called 'geo-stationary satellite' The orbit of a geostationary satellite is called 'Parking orbit'.

- **Time Period :** T = 24 hours.
- **Height of the geostationary satellite :**

$$h=\left[\frac{T^2GM_E}{4\pi^2}\right]^{1/3}-R_E\cong 36,000\text{ km approx}$$

- **Uses :**
  - Radio communication
  - Transmission of TV and telephone signals.

Polar satellite

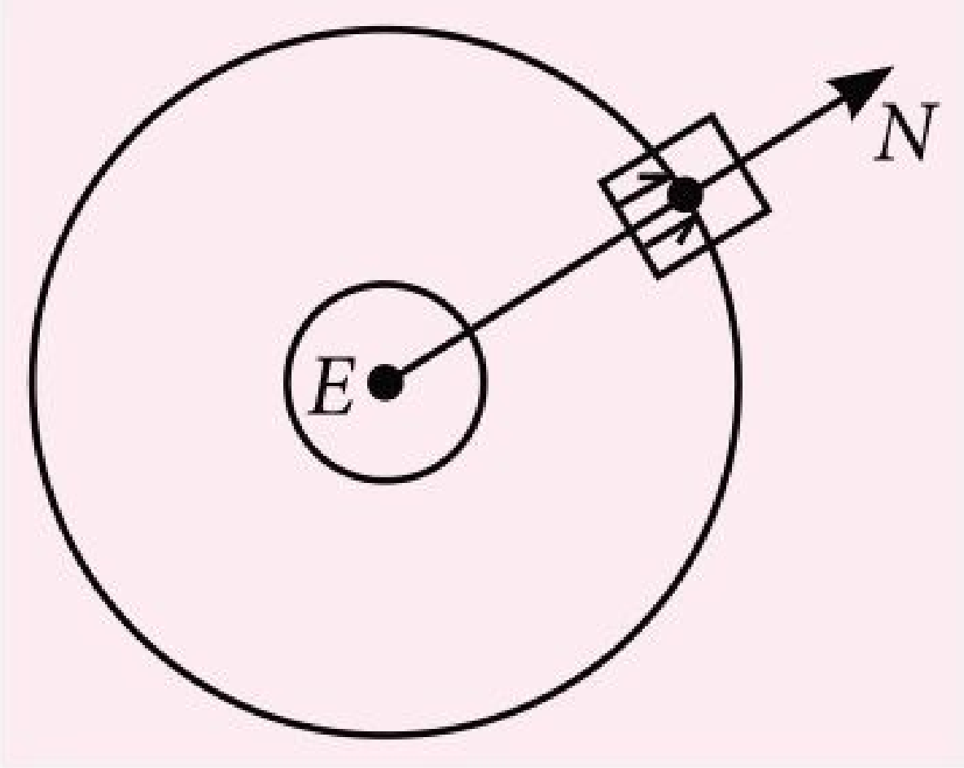
The satellites revolve around the earth in a circles north to south orbit which passes over the north and south poles.

- Low altitude satellite ≈ 500 – 800 km.
- Angle of inclination of orbit with equatorial plane is 90°.
- They crosses equator of the earth daily at same time hence they are also called sun-synchronous satellites.
- **Uses :**
  - Remote sensing
  - Meteorology and environmental studies

WEIGHTLESSNESS IN A SATELLITE

The radial acceleration of the satellite is given by

$$a_r=\frac{F_r}{m}=\frac{GMm}{r^2\times m}=\frac{GM}{r^2}$$



For a astronaut inside the satellite, we have

$$\frac{GMm_a}{r^2}-N-m_aa_r=0$$

where m_a is mass of astronaut, a_r is radial acceleration of satellite and N is normal reaction on the astronaut.

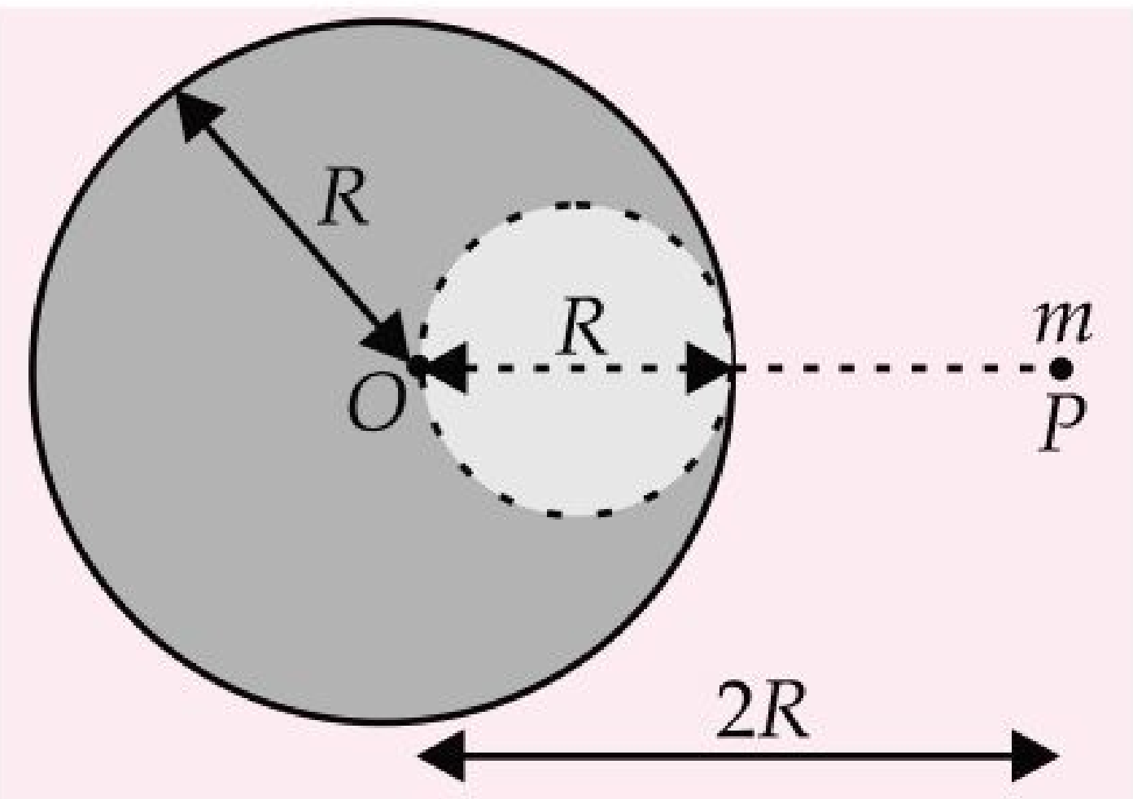
or, $\frac{GMm_a}{r^2}-N-\frac{GMm_a}{r^2}=0$

$\Rightarrow\ N=0$

Hence, the astronaut feels weightlessness.

WRAP it up!

1. A uniform sphere of mass M and radius R exerts a force F on a small mass m situated at a distance $2R$ from the centre O of the sphere. A spherical portion of diameter R is cut from the sphere as shown in figure. What will be the force of attraction between the remaining part of the sphere and the mass m?



(a) $\frac{F}{8}$ (b) $\frac{7F}{9}$ (c) $\frac{F}{9}$ (d) $\frac{2F}{7}$

2. Two astronauts have deserted their spaceship in a region of space far from the gravitational attraction of any other body. Each has a mass of 60 kg and they are 60 m apart. They are initially at rest relative to one another. How long will it be before the gravitational attraction brings them 2.2 cm closer together?
(Given $G = 6.66\times10^{-11}$ N m^2 kg^{-2})

(a) 10^5 s (b) $10^5\times\sqrt{2}$ s
(c) 10^6 s (d) $10^6\times\sqrt{2}$ s

3. The minimum and maximum distances of a satellite from the centre of the earth are $3R$ and $6R$ respectively, where R is the radius of the earth. The radius of curvature of the satellite orbit of the point of maximum distance is

(a) $\frac{2R}{3}$ (b) $\frac{4R}{3}$
(c) $4R$ (d) $\frac{16R}{3}$

4. A uniform solid sphere of radius R produces a gravitational acceleration a_g on its surface. At what two distances from the centre of the sphere the acceleration due to gravity is $a_g/9$?

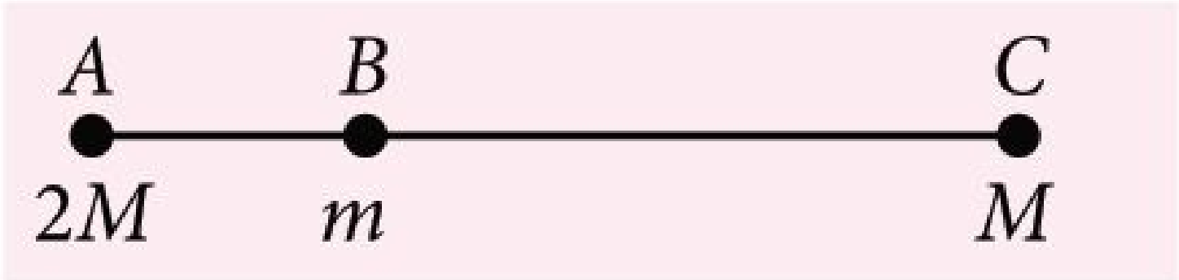
(a) $9R$, $0.50R$ (b) $3R$, $R/9$
(c) $3R$, $0.33R$ (d) $3R$, $R/8$

5. An artificial satellite is moving in a circular orbit around the earth with a speed equal to one fourth of the magnitude of escape velocity from earth. The

height of satellite above earth's surface is nR. Then the value of n is

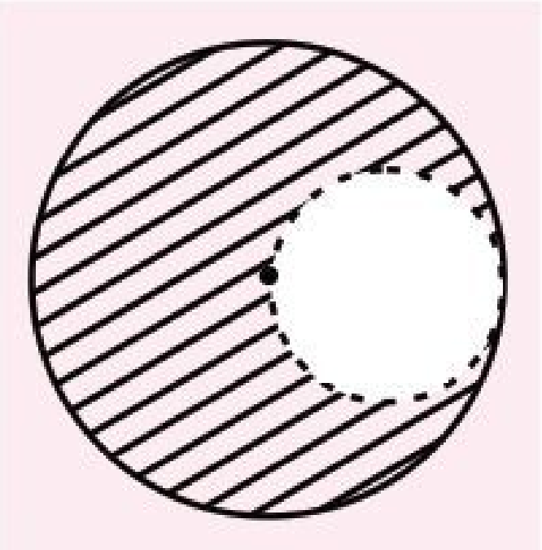
(a) 2 (b) 7 (c) 4 (d) 6

6. Particles of masses $2M$, m and M are, respectively, at points A, B and C with $AB = \frac{1}{2}(BC)$ as shown in figure. m is very much smaller than M and at time $t = 0$, they are all at rest as given in figure. At subsequent times before any collision takes place,



(a) m will remain at rest.
(b) m will move towards M.
(c) m will move towards $2M$.
(d) m will have oscillatory motion.

7. From a solid sphere of mass M and radius R, a spherical portion of radius $\frac{R}{2}$ is removed, as shown in the figure. Taking gravitational potential $V = 0$ at $r = \infty$, the potential at the centre of the cavity thus formed is (G = gravitational constant)



(a) $\frac{-2GM}{3R}$ (b) $\frac{-2GM}{R}$

(c) $\frac{-GM}{2R}$ (d) $\frac{-GM}{R}$

8. If the earth's satellite of mass m orbiting at a distance $2R$ from the centre of earth has to be transferred into the orbit of radius $4R$, the amount of energy required is (R is the radius of earth)

(a) mgR (b) $\frac{mgR}{4}$ (c) $\frac{mgR}{2}$ (d) $\frac{mgR}{8}$

9. What is a period of revolution of earth satellite? (Ignore the height of satellite above the surface of earth. Given : $g = 10$ m s^{-2}, $R_E = 6400$ km, $\pi = 3.14$)

(a) 83.73 minutes (b) 85 minutes
(c) 90 minutes (d) 156 minutes

10. A projectile is fired vertically upward from the surface of earth with a velocity of nv_e, where v_e is the escape velocity and $n < 1$. Neglecting air resistance, the maximum height to which it will rise, measured from the centre of the earth, is (R is the radius of the earth)

(a) $\frac{R}{1-n^2}$ (b) $\frac{R}{n^2}$ (c) $\frac{1-n^2}{R}$ (d) $\frac{n^2}{R}$

11. A satellite revolves in elliptical orbit around a planet of mass M situated at the centre of the path. Its time period is T. The length of the major axis of the path is (neglect the gravitational effect of other objects in space)

(a) $2\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$ (b) $\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$

(c) $\frac{1}{2}\left[\frac{GMT^2}{4\pi^2}\right]^{1/3}$ (d) none of these

12. Two satellites S_1 and S_2 are revolving round a planet in coplanar and concentric circular orbit of radii R_1 and R_2 in the same direction respectively. Their respective periods of revolution are 1 hr and 8 hr. The radius of the orbit of satellite S_1 is equal to 10^3 km. Find the relative speed (in km h^{-1}) when they are closest.

(a) $2\pi \times 10^3$ (b) $\pi \times 10^3$

(c) $\frac{\pi}{2} \times 10^3$ (d) $\frac{\pi}{3} \times 10^3$

13. The acceleration due to gravity at a height 4 km above the earth is the same as at a depth d below the surface of earth. Then

(a) $d = 1$ km (b) $d = 4$ km
(c) $d = 8$ km (d) $d = 16$ km

14. A planet moving along an elliptical orbit is closest to the sun at a distance r_1 and farthest away at a distance of r_2. If v_1 and v_2 are the linear velocities at these points respectively, then the ratio $\frac{v_1}{v_2}$ is

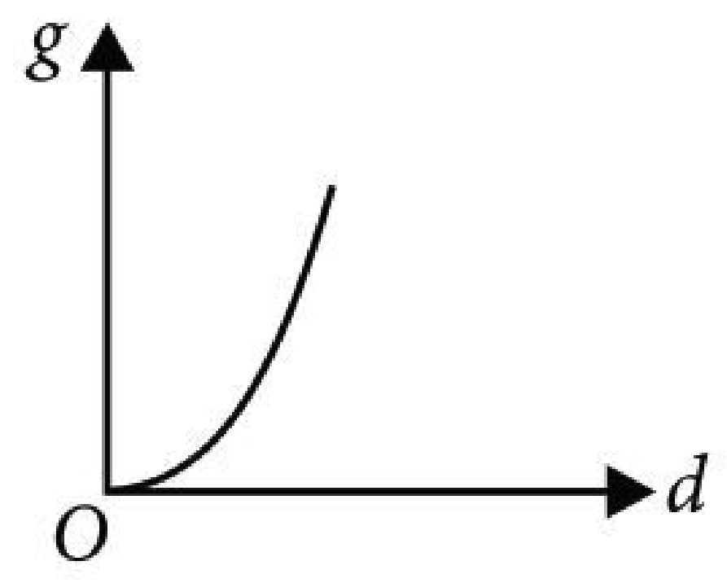
(a) $\frac{2r_1}{r_2}$ (b) $\frac{r_2}{r_1}$

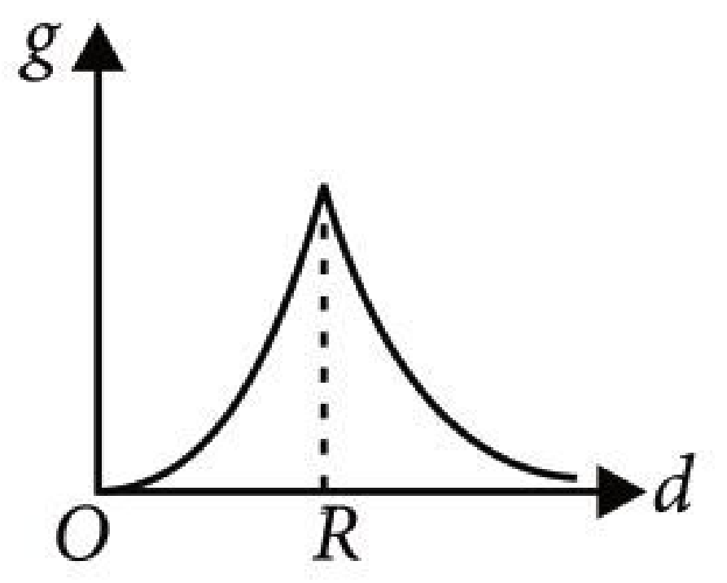
(c) $\frac{r_1}{r_2}$ (d) $\frac{r_2}{2r_1}$

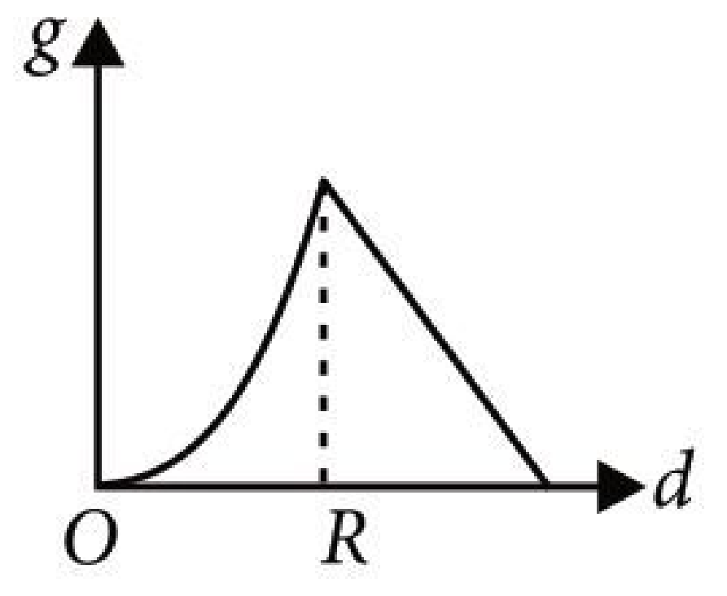
15. A rocket starts vertically upwards with speed v_0. If R is the radius of earth and v is the speed of rocket at a height h then find the maximum height reached by the rocket when fired with speed 0.9 times escape velocity.

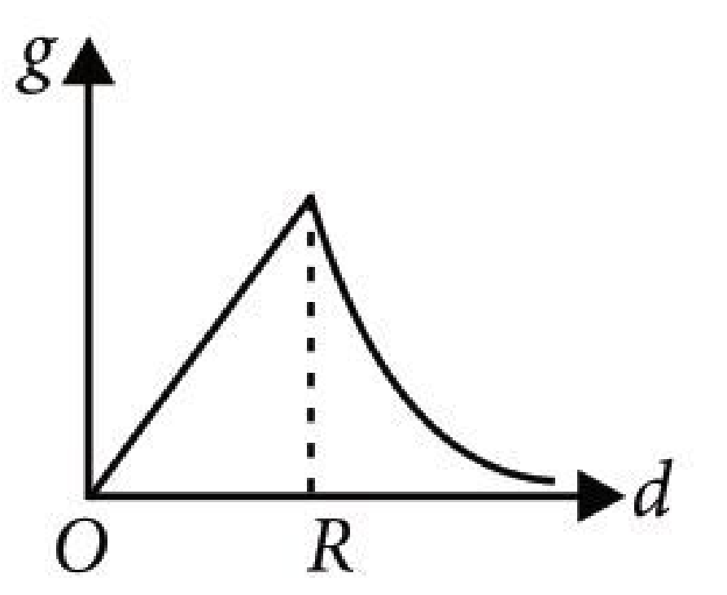
(a) $1.25R$ (b) $4.26R$ (c) $5.12R$ (d) $0.81R$

16. The variation of acceleration due to gravity g with distance d from centre of the Earth is best represented by (R = Earth's radius)

(a)


(b)


(c)


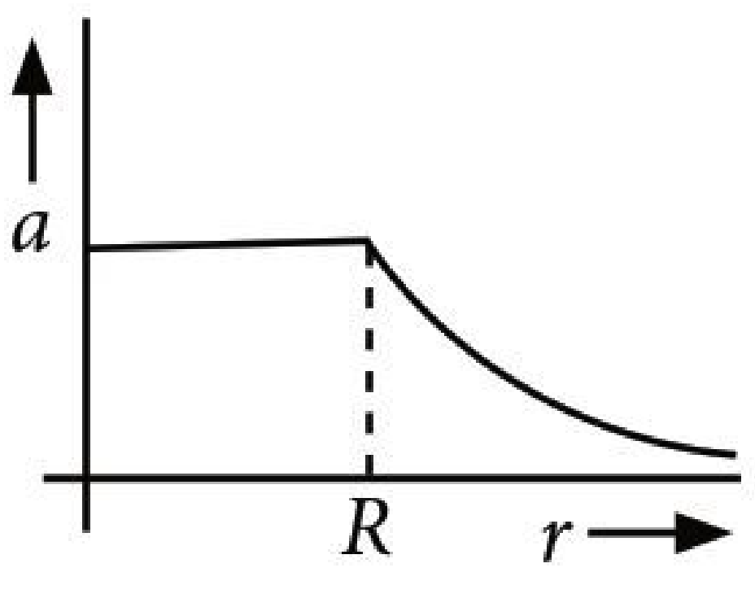
(d)


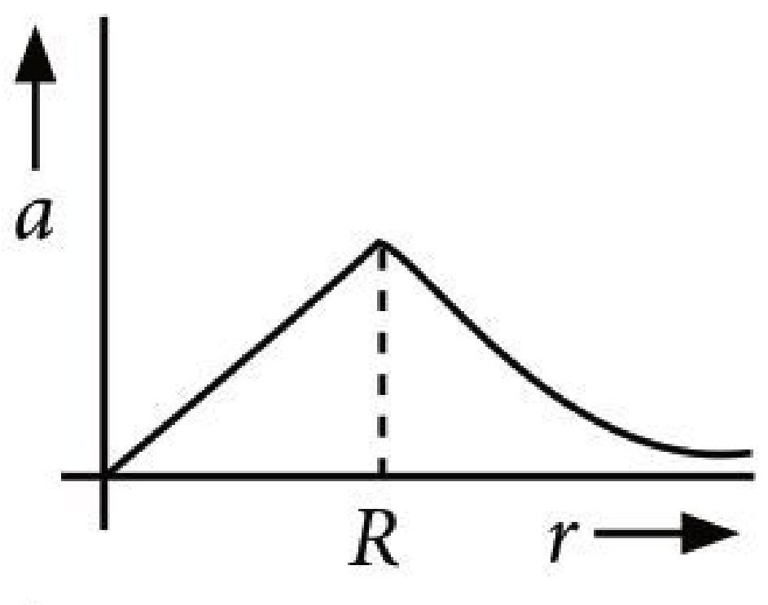
17. If the Earth has no rotational motion, the weight of a person on the equator is W. Determine the speed with which the earth would have to rotate about its axis so that the person at the equator will weigh 1/2 W. Radius of the Earth is 6400 km and $g = 10 \text{ m s}^{-2}$.

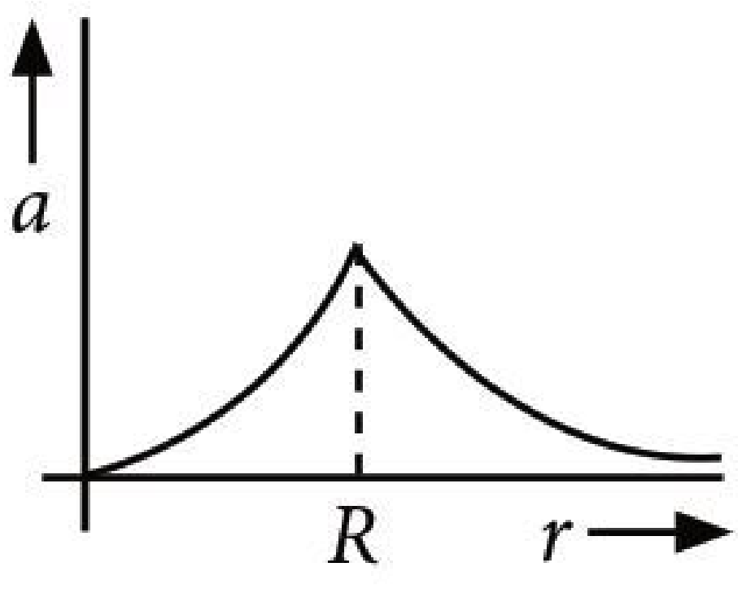
(a) $8.8 \times 10^{-4} \text{ rad s}^{-1}$ (b) $6.8 \times 10^{-4} \text{ rad s}^{-1}$

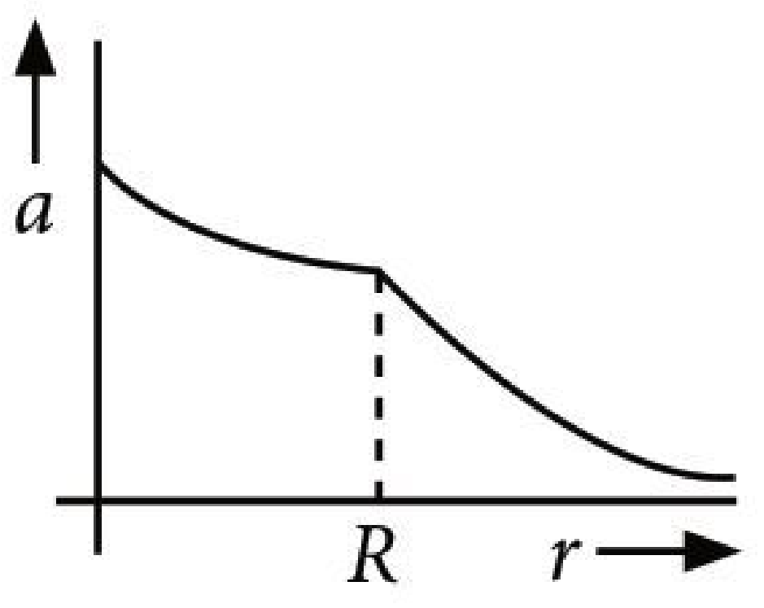
(c) $2.8 \times 10^{-4} \text{ rad s}^{-1}$ (d) $1.1 \times 10^{-4} \text{ rad s}^{-1}$

18. The mass density of a spherical body is given by $\rho(r) = \frac{k}{r}$ for $r \le R$ and $\rho(r) = 0$ for $r > R$, where r is the distance from the centre. The correct graph that describes qualitatively the acceleration, a of a test particle as a function of r is

(a)


(b)


(c)


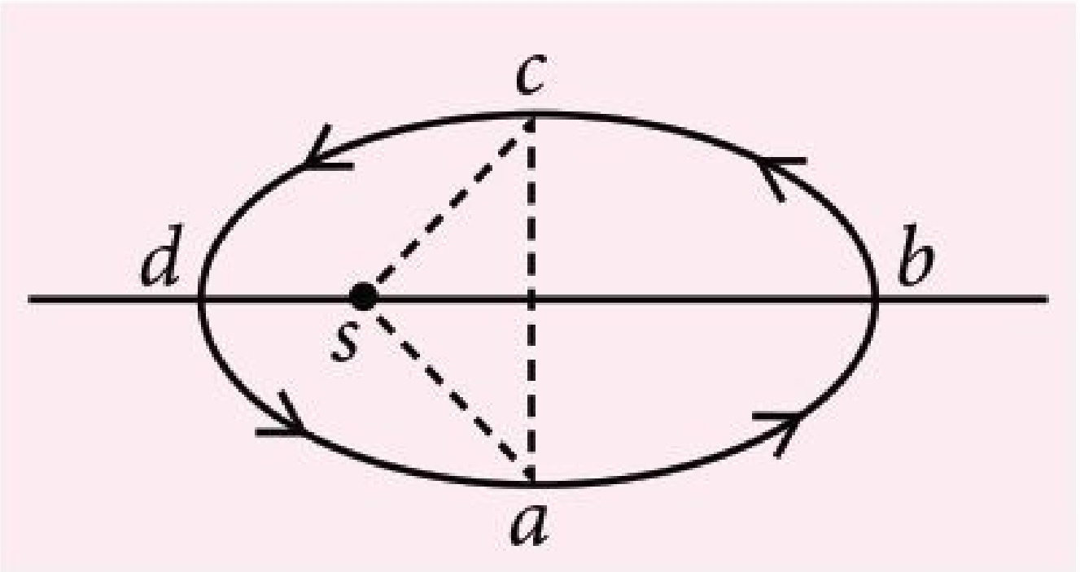
(d)


19. A rocket is launched normal to the surface of the Earth, away from the Sun, along the line joining the Sun and the Earth. The Sun is 3×10^5 times heavier than the Earth and is at a distance 2.5×10^4 times larger than the radius of the Earth. The escape velocity from Earth's gravitational field is $v_e = 11.2 \text{ km s}^{-1}$. The minimum initial velocity (v_s) required for the rocket to be able to leave the Sun-Earth system is closest to (Ignore the rotation and revolution of the Earth and the presence of any other planet)

(a) $v_s = 62 \text{ km s}^{-1}$ (b) $v_s = 22 \text{ km s}^{-1}$

(c) $v_s = 72 \text{ km s}^{-1}$ (d) $v_s = 42 \text{ km s}^{-1}$

20. Figure shows elliptical path $abcd$ of a planet around the sun S such that the area of triangle csa is $\frac{1}{4}$ the area of the ellipse. In figure, db is the semi-major axis, and ca as the semi-minor axis. If t_1 is the time taken for planet to go over path abc and t_2 for path taken over cda, then



(a) $t_1 = 4t_2$ (b) $t_1 = 2t_2$ (c) $t_1 = 3t_2$ (d) $t_1 = t_2$

SOLUTIONS

1. (b) : Gravitational force of attraction on mass m at P due to solid sphere is

$$F = \frac{GMm}{(2R)^2} = \frac{GMm}{4R^2} \quad \text{or} \quad \frac{GMm}{R^2} = 4F \qquad \text{...(i)}$$

Mass of the spherical portion removed from sphere

$$M' = \frac{M}{\frac{4}{3}\pi R^3} \times \frac{4}{3}\pi\left(\frac{R}{2}\right)^3 = \frac{M}{8}$$

Gravitational force of attraction on mass m at point P if mass of the spherical portion removed is present there, is

$$F' = \frac{G(M/8)m}{\left(\frac{3R}{2}\right)^2} = \frac{GMm}{R^2} \times \frac{1}{8} \times \frac{4}{9}$$

$$= 4F \times \frac{1}{8} \times \frac{4}{9} = \frac{2F}{9} \qquad \text{(Using (i))}$$

∴ Gravitational force of attraction on mass m at P due to remaining part of the sphere is

$$F'' = F - F' = F - \frac{2F}{9} = \frac{7F}{9}$$

2. (b) : Acceleration of first astronaut,

$$a_1 = \frac{G\, m_1 m_2}{r^2} \times \frac{1}{m_1} = \frac{G\, m_2}{r^2}$$

Acceleration of second astronaut,

$$a_2 = \frac{G\, m_1 m_2}{r^2} \times \frac{1}{m_2} = \frac{G\, m_1}{r^2}$$

Net acceleration of approach is

$$a = a_1 + a_2 = \frac{G}{r^2}\,(m_1 + m_2)$$

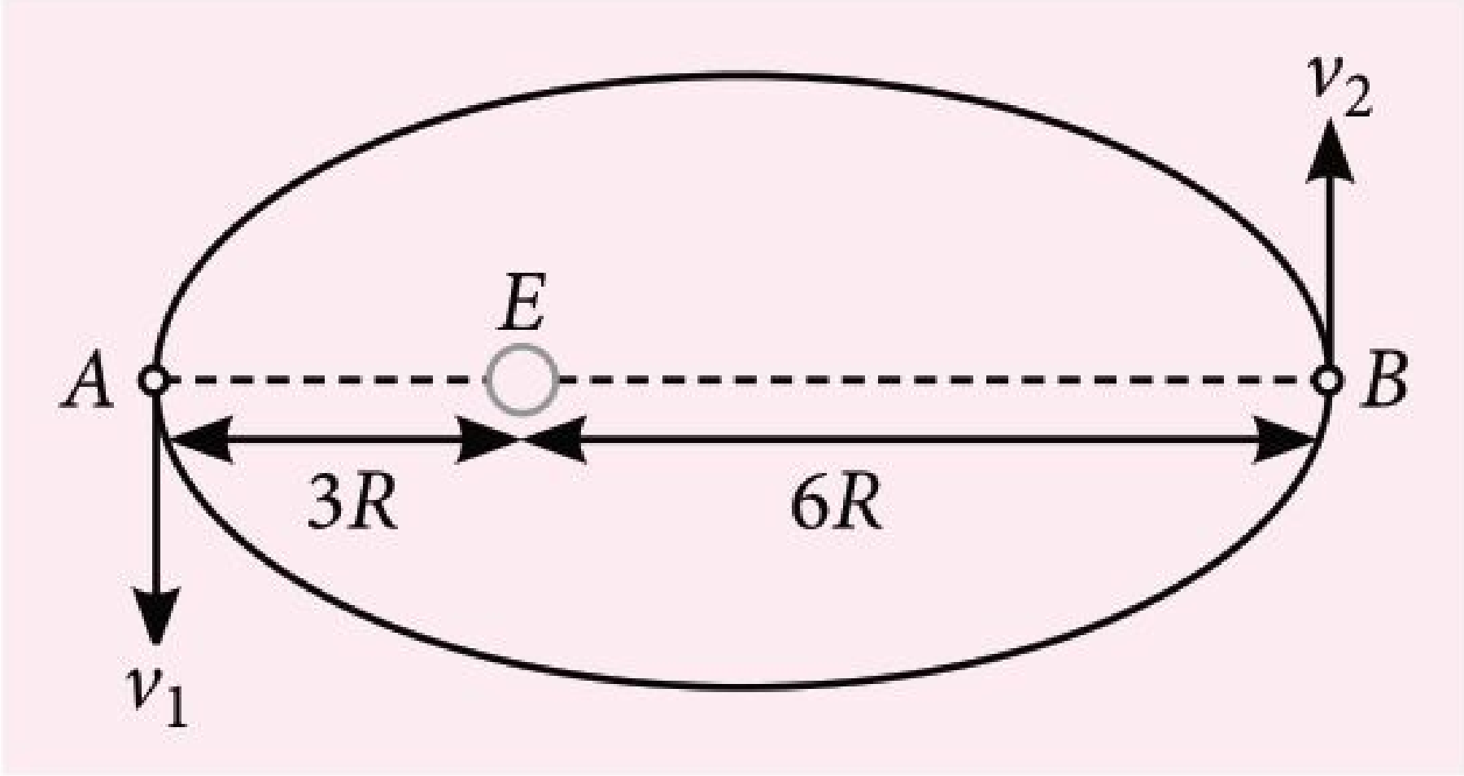
$$= \frac{6.66 \times 10^{-11}}{(60)^2} \times (60 + 60) = 2.22 \times 10^{-12} \text{ m s}^{-2}$$

Now, $s = \frac{1}{2}at^2$

or $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2\times 2.2\times 10^{-2}}{2.22\times 10^{-12}}} = 10^5\sqrt{2}\text{ s}$

3. **(c) :** Refer to figure and using law of conservation of angular momentum, we have

$mv_1\,(3R) = mv_2\,(6R)$ or $v_1 = 2v_2$ ...(i)



According to law of conservation of mechanical energy,

$$\frac{1}{2}mv_1^2 - \frac{GMm}{3R} = \frac{1}{2}mv_2^2 - \frac{GMm}{6R} \quad \text{...(ii)}$$

Solving (i) and (ii), we get

$$v_1 = \sqrt{\frac{4GM}{9R}} \quad \text{and} \quad v_2 = \sqrt{\frac{GM}{9R}}$$

If r is the radius of curvature of the orbital path of satellite at B, then

$$\frac{mv_2^2}{r} = \frac{GMm}{(6R)^2} \quad \text{or} \quad r = \frac{36R^2v_2^2}{GM} = \frac{36R^2}{GM}\times\frac{GM}{9R} = 4R$$

4. **(b):** At a height h above the surface,

$$g_h = g\left(\frac{R}{R+h}\right)^2; \text{ Here, } g_h = \frac{a_g}{9} \text{ and } g = a_g$$

$$\therefore \quad \frac{a_g}{9} = a_g\left[\frac{R}{R+h}\right]^2 \quad \text{or} \quad \frac{R}{R+h} = \frac{1}{3}$$

or $R + h = 3R$ or $h = 2R$

$\therefore$ Distance from the centre $= R + h = R + 2R = 3R$

At a depth d below the surface, $g_d = g\left(1 - \frac{d}{R}\right)$

Here, $g_d = \frac{a_g}{9}$ and $g = a_g$

$$\therefore \quad \frac{a_g}{9} = a_g\left(1 - \frac{d}{R}\right) \quad \text{or} \quad d = \frac{8}{9}R$$

$\therefore$ Distance from the centre $= R - d = R - \frac{8}{9}R = \frac{R}{9}$

5. **(b):** Escape velocity, $v_e = \sqrt{2gR}$, where g is acceleration due to gravity on surface of earth and R the radius of earth.

Orbital velocity, $v_0 = \frac{1}{4}\sqrt{2gR} = \frac{\sqrt{gR}}{8}$

If h is the height of satellite above earth then

$$\frac{mv_0^2}{R+h} = \frac{GMm}{(R+h)^2} \quad \text{or} \quad v_0^2 = \frac{GM}{R+h} = \frac{gR^2}{(R+h)}$$

$$\therefore \quad \left(\sqrt{\frac{gR}{8}}\right)^2 = \frac{gR^2}{R+h}; \ \frac{gR}{8} = \frac{gR^2}{R+h}$$

$R + h = 8R \Rightarrow h = 7R$. Hence $n = 7$

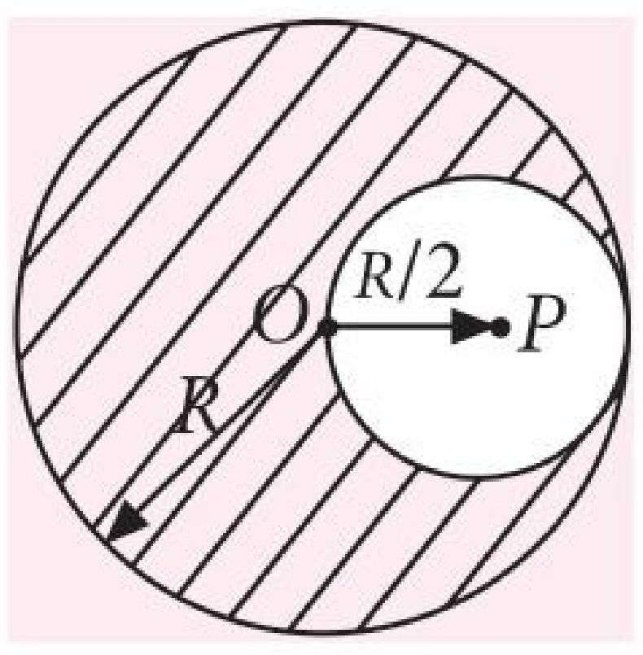
6. **(c) :** Force on B due to $A = F_{BA} = \frac{G(2Mm)}{(AB)^2}$ towards BA

Force on B due to $C = F_{BC} = \frac{GMm}{(BC)^2}$ towards BC

$$\Rightarrow \quad F_{BC} = \frac{GMm}{(2AB)^2} = \frac{GMm}{4(AB)^2} < F_{BA} \ (\because BC = 2AB)$$

Hence, m will move towards the mass $2M$.

7. **(d):** Potential at point P (centre of cavity) before removing the spherical portion,



$$V_1 = \frac{-GM}{2R^3}\left(3R^2 - \left(\frac{R}{2}\right)^2\right) = \frac{-11GM}{8R}$$

Mass of spherical portion to be removed,

$$M' = \frac{MV'}{V} = \frac{M\frac{4\pi}{3}\left(\frac{R}{2}\right)^3}{\frac{4\pi}{3}R^3} = \frac{M}{8}$$

Potential at point P due to spherical portion to be removed,

$$V_2 = \frac{-3GM'}{2R'} = \frac{-3G(M/8)}{2(R/2)} = \frac{-3GM}{8R}$$

$\therefore$ Potential at the centre of cavity formed,

$$V_P = V_1 - V_2 = \frac{-11GM}{8R} - \left(\frac{-3GM}{8R}\right) = \frac{-GM}{R}$$

8. **(d):** Energy of the satellite in an orbit of radius r is $E = -\frac{GMm}{2r}$ where M and m are the masses of the earth and satellite respectively.

Initial energy of the satellite is $E_i = -\frac{GMm}{2(2R)}$

Final energy of the satellite is $E_f = -\frac{GMm}{2(4R)}$

Amount of energy required is $\Delta E = E_f - E_i$

$$= -\frac{GMm}{2(4R)} - \left(-\frac{GMm}{2(2R)}\right)$$

$$= \frac{GMm}{2R}\left[\frac{1}{2}-\frac{1}{4}\right] = \frac{GMm}{8R} = \frac{mgR}{8} \quad \left(\because g = \frac{GM}{R^2}\right)$$

9. (a) : The period of revolution of earth satellite is

$$T = 2\pi\sqrt{\frac{(R_E+h)^3}{gR_E^2}}\ ;\ \text{Neglecting } h, \text{ then } T = 2\pi\sqrt{\frac{R_E}{g}}$$

Substituting the given values, we get

$$T = 2 \times 3.14\sqrt{\frac{6400\times 10^3}{10}}\ \text{s} = 5024\ \text{s} = 83.73\ \text{minutes}$$

10. (a) : Let the projectile be fired vertically upward from the earth's surface with velocity v and it reaches a maximum height h. By the law of conservation of mechanical energy, $\frac{1}{2}mv^2 - \frac{GMm}{R} = -\frac{GMm}{R+h}$

or $\frac{1}{2}mv^2 = GMm\left[\frac{1}{R} - \frac{1}{R+h}\right] = \frac{GMmh}{(R)(R+h)}$

or $\frac{1}{2}mv^2 = \frac{mghR}{(R+h)} \quad \left(\because g = \frac{GM}{R^2}\right)$

As per question,

$v = nv_e = n\sqrt{2gR}$ and $h = r - R \quad (\because v_e = \sqrt{2gR})$

where r is the distance from the centre of the earth.

$\therefore \quad \frac{1}{2}mn^2 2gR = \frac{mg(r-R)R}{r}$

or $n^2 = \frac{r-R}{r}$ or $(1-n^2)r = R$ or $r = \frac{R}{1-n^2}$

11. (a) : Since the planet is at the center, the focus and centre of the elliptical path coincide, and the elliptical path becomes circular and the major axis is nothing but the diameter. For a circular path,

$$\frac{mv^2}{r} = \frac{GM}{r^2}m \text{ or } v = \sqrt{\frac{GM}{r}}$$

$$\text{Also } T = \frac{2\pi r}{v} = \frac{2\pi r^{3/2}}{\sqrt{GM}} \text{ or } T^2 = \frac{4\pi^2 r^3}{GM}$$

$$\Rightarrow \text{Radius, } r = \left(\frac{GMT^2}{4\pi}\right)^{1/3}$$

$$\Rightarrow \text{Diameter (major axis)} = 2\left(\frac{GMT^2}{4\pi}\right)^{1/3}$$

PUBLIC NOTICE

JEE MAIN 2023

The Department of Higher Education, Ministry of Education, Government of India has entrusted the responsibility of conducting the Joint Entrance Examination (JEE Main) to the NTA from 2019 onwards.

The Joint Entrance Examination (JEE (Main) comprises two papers. **Paper 1 (B.E./B.Tech.)** is conducted for admission to Undergraduate Engineering Programs (B.E/B. Tech) at NITs, IIITs, other Centrally Funded Technical Institutions (CFTIs), Institutions/Universities funded/recognized by participating State Governments. It is also an eligibility test for JEE (Advanced), which is conducted for admission to IITs. **Paper 2** is conducted for admission to **B. Arch and B. Planning** courses in the Country.

For Academic Session 2023-24, it has been decided that the **JEE (Main) – 2023 will be conducted in two Sessions i.e. Session 1 (January 2023) and Session 2 (April 2023)**. The details for the **Session 1 (January 2023)** are given below :

Online Submission of Application Form	**15 December 2022 to 12 January 2023 (up to 09:00 P.M.)**
Last date of successful transaction of fee through Credit/Debit Card/ Net-Banking/UPI	**12 January 2023 (up to 11:50 P.M.)**
Announcement of the City of Examination	**Second week of the January 2023**
Downloading of Admit Cards from the NTA website	**Third week of the January 2023**
Date of Examination	**24, 25, 27, 28, 29, 30 and 31 January 2023**
Centre, Date, and Shift	As indicated on Admit Card
Display of Recorded Responses and Answer Keys	To be announced later on the website
Website(s)	www.nta.ac.in, https://jeemain.nta.nic.in/
Declaration of Result on the NTA website	*To be announced later on the website*

JEE (Main) - 2023 will be conducted in **13 languages** i.e. **English, Hindi, Assamese, Bengali, Gujarati, Kannada, Malayalam, Marathi, Odia, Punjabi, Tamil, Telugu, and Urdu.**

In the first session of JEE (Main) - 2023, only Session 1 will be visible and candidates can opt for that. In the next session, Session 2 will be visible, and the candidates can opt for that Session. The application window for Session 2 will be re-opened as per the details available in the Information Bulletin and will also be notified separately through a Public Notice.

For Papers, Scheme, Timing, eligibility and other information, candidates are requested to please check the Information Bulletin of JEE (Main) – 2023 available on the website: https://jeemain.nta.nic.in/

12. (b) : By Kepler's 3rd law, $\frac{T^2}{R^3}$ = constant

$$\therefore \quad \frac{T_1^2}{R_1^3} = \frac{T_2^2}{R_2^3} \quad \text{or} \quad \frac{1}{(10^3)^3} = \frac{64}{R_2^3} \quad \text{or} \quad R_2 = 4 \times 10^3 \text{ km}$$

Distance travelled in one revolution,
$S_1 = 2\pi R_1 = 2\pi \times 10^3$ and $S_2 = 2\pi R_2 = 2\pi \times 4 \times 10^3$

$$v_1 = \frac{S_1}{T_1} = \frac{2\pi \times 10^3}{1} = 2\pi \times 10^3 \text{ km h}^{-1}$$

$$\text{and } v_2 = \frac{S_2}{T_2} = \frac{2\pi \times 4 \times 10^3}{8} = \pi \times 10^3 \text{ km h}^{-1}$$

$\therefore$ Relative velocity $v_1 - v_2 = 2\pi \times 10^3 - \pi \times 10^3 = \pi \times 10^3 \text{ km h}^{-1}$

13. (c) : The acceleration due to gravity at a height h is given as $g_h = g(1 - 2h/R_e)$ where R_e is radius of earth. The acceleration due to gravity at a depth d is given as $g_d = g(1 - d/R_e)$
Given, $g_h = g_d$

$$\therefore \quad g\left(1 - \frac{2h}{R_e}\right) = g\left(1 - \frac{d}{R_e}\right)$$

$\therefore \quad d = 2h = 2 \times 4 = 8$ km $\qquad (\because h = 1 \text{ km})$

14. (b) : According to the law of conservation of angular momentum $L_1 = L_2$

$$mv_1r_1 = mv_2r_2 \quad \text{or} \quad v_1r_1 = v_2r_2 \quad \text{or} \quad \frac{v_1}{v_2} = \frac{r_2}{r_1}$$

15. (b) : Kinetic energy on the surface of earth = $\frac{1}{2}mv_0^2$

Potential energy on the surface of earth = $\frac{-GMm}{R}$

Total energy = $\frac{1}{2}mv_0^2 - \frac{GMm}{R}$

Kinetic energy at a height h = $\frac{1}{2}mv^2$

Potential energy at such height = $\frac{-GMm}{(R+h)}$

Total energy = $\frac{1}{2}mv^2 - \frac{GMm}{R+h}$

By the principle of conservation of energy,

$$\frac{1}{2}mv^2 - \frac{GMm}{R+h} = \frac{1}{2}mv_0^2 - \frac{GMm}{R}$$

$$\frac{1}{2}(v_0^2 - v^2) = \frac{GM}{R} - \frac{GM}{(R+h)}$$

But $GM = gR^2$

$$\frac{1}{2}(v_0^2 - v^2) = \frac{gR^2h}{R(R+h)}, \quad v_0^2 - v^2 = \frac{2gRh}{R+h} = \frac{2gh}{1 + \frac{h}{R}}$$

At maximum height $v = 0$,

v_0 = 90% of escape velocity = $0.9\sqrt{2gR}$

$$\therefore \quad \left(0.9\sqrt{2gR}\right)^2 - 0 = \frac{2gh_{\text{max}}}{1 + \frac{h_{\text{max}}}{R}}; \quad 0.81R = \frac{h_{\text{max}}}{1 + \frac{h_{\text{max}}}{R}}$$

$0.81R = 0.81\, h_{\text{max}} - h_{\text{max}}$, or $0.19\, h_{\text{max}} = 0.81R$

$$h_{\text{max}} = \frac{0.81R}{0.19} = 4.26 \text{ R}$$

16. (d)

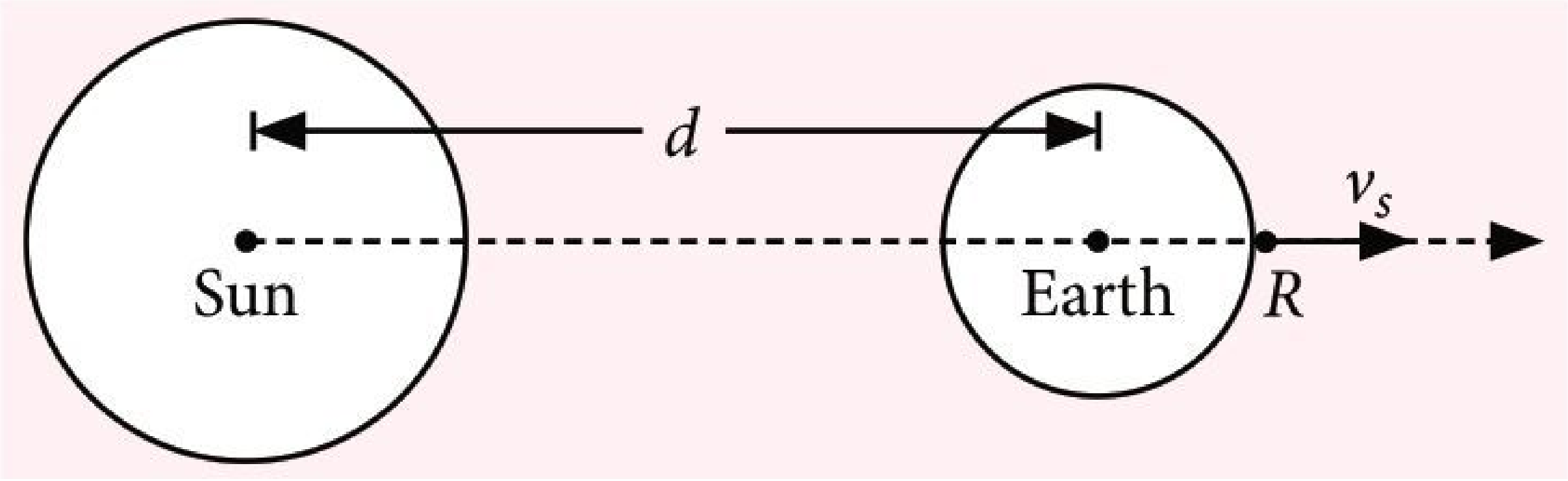
17. (a) : Here, the weight of person on the equator = W
If earth rotates about its axis, then weight = 1W/2
Radius of the earth = 6400 km
The acceleration due to gravity at the equator,
$g_e = g - \omega^2 R \cos^2\theta$

$$\frac{1}{2}g = g - \omega^2 R \cos^2 0° \text{ or } \omega^2 R = \frac{g}{2}$$

$$\omega = \sqrt{\frac{g}{2R}} = \sqrt{\frac{10}{2 \times 6400 \times 10^3}} = 8.8 \times 10^{-4} \text{ rad s}^{-1}$$

18. (a)

19. (d) :



Given : Mass of the sun, $M_s = 3 \times 10^5 \times$ mass of the earth
$= 3 \times 10^5 M_e$
Distance between the sun and the earth,
$d = 2.5 \times 10^4 \times$ radius of the earth $= 2.5 \times 10^4 R_e$,
Escape speed, $v_e = 11.2 \text{ km s}^{-1}$

$$\therefore \quad v_e = \sqrt{\frac{2GM_e}{R_e}} = 11.2 \text{ km s}^{-1}$$

Minimum velocity required for the rocket to escape from the given earth – sun system = v_s
Using energy conservation for the given situation,

$$\frac{1}{2}mv_s^2 = \frac{GM_em}{R_e} + \frac{GM_sm}{d + R_e} = \frac{GM_em}{R_e} + \frac{G \times 3 \times 10^5 M_em}{(2.5 \times 10^4 R_e + R_e)}$$

$$\therefore \quad v_s^2 = \frac{2GM_e}{R_e} + \frac{24GM_e}{R_e} \qquad (\because 2.5 \times 10^4 >> 1)$$

$\Rightarrow v_s^2 = v_e^2 + 12v_e^2 = 13v_e^2$

or $v_s = \sqrt{13}\, v_e = 40.38 \text{ km s}^{-1} \approx 42 \text{ km s}^{-1}$

20. (c)

GK CORNER

Enhance Your General Knowledge with Current Updates!

SPORTS

- Portugal's Cristiano Ronaldo has become the first male player to score in 5 World Cups.
- Manika Batra (Table Tennis player) becomes the first Indian woman to win a medal at Asian Cup (ATTU Asian Cup Tournament in Bangkok, Thailand).
- Table Tennis player Achanta Sharath Kamal has become the first player from India to get elected in the Athletes' Commission of the International Table Tennis Federation (ITTF).
- Indian cricketer Virat Kohli has created history by becoming the first batsman to reach 4000 runs in T20 Internationals.

  Indian batsman, Suryakumar Yadav has become the world's number one batsman in T20 Internationals and also become the second Indian player to hold the top T20I batter ranking.

Major Dhyan Chand Khel Ratna Award 2022 is the highest sports award established in 1991. It was previously known as Rajiv Gandhi Khel Ratna Award. Vishwanath Anand, the chess champion was the first person to be awarded by the Indian Govt, with Khel Ratna. The winner list of 2022 award:

Name of the sportsperson	Discipline
Ms Ashwini Akkunji C.	Athletics
Shri Dharamvir Singh	Hockey
Shri B.C. Suresh	Kabaddi
Shri Nir Bahadur Gurung	Para Athletics
Achanta Sharath Kamal	Table tennis

FIFA World Cup 2022:

- Edition-22nd
- Host Country – Qatar
- Venue – There were eight venues in total. Final match was held at Lusail stadium, Lusail.
- Argentina won the ensuing penalty shoot out 4-2 to win their third FIFA World Cup title and first since 1986.
- First Match – Between Qatar and Ecuador
- Stephanie Frappart (French) to be 1st woman referee in FIFA world cup.

Canada won their first Davis Cup title after Felix Auger-Aliassime beat Australia's Alex de Minaur by 6-3, 6-4 in the second match of the finals.

ABOUT DAVIS CUP:

The Davis Cup is also called the World Cup of Tennis. This is the Premier International team event in Men's Tennis. Also, Billie Jean King Cup is the Premier International Team competition in Women's Tennis.

- In yet another milestone moment for boxing, India has been named as the host country for the 2023 IBA Women's World Boxing Championship. A Memorandum of Understanding (MoU) was signed between the International Boxing Association (IBA) and the Boxing Federation of India (BFI). The MoU was signed in the presence of IBA President Umar Kremlev and BFI President Ajay Singh. The occasion was also felicitated by world champion Nikhat Zareen.
- Pramod Bhagat and Manisha Ramadass won gold medals in singles at the BWF Para-Badminton World Championships in Tokyo. The reigning Paralympic

gold medalist Pramod Bhagat beat compatriot Nitesh Kumar.

- The Indian men's team, led by the seasoned Saurav Ghosal, clinched its first-ever gold at the Asian Squash Team Championships with a 2-0 win over Kuwait in the final.
- Top-seeded Indian Grandmaster, R Praggnanandhaa and compatriot P V Nandhidhaa won the titles in the Open and women's sections respectively in the Asian Continental Chess championship.
- The Indian men's team has clinched their first-ever gold at the Asian Squash Team Championships, held in Cheongju, South Korea. The Indian team has defeated Kuwait by 2-0 in final.
- The third edition of Khelo India National University Games (2023-24) will be held in four cities of the state Uttar Pradesh.
  These cities are Lucknow (main host city), Gorakhpur, Varanasi and Noida.
- Achanta Sharath Kamal has become the first Indian to be elected in the Athletes' Commission of the International Table Tennis Federation.
  He will serve in the Commission from 2022 to 2026.
- Kerala is set to host the Track Asia Cup 2022 Cycling Tournament. Track Asia Cup is one of the biggest cycling events and will be held at LNCPE Outdoor Velodrome from 25th November 2022 to 28th November 2022. In the Track Asia Cup 2022, around 200 cyclists will participate from over 25 countries in Asia. The event is being conducted outside Delhi for the first time.
- In a landmark decision, the BCCI on Thursday announced equal match fee for its centrally-contracted female and male players in a bid to promote gender equality in the country's most popular sport.
  BCCI secretary Jay Shah took the decision to tackle discrimination.

Test Yourself!

1. Who becomes the first Indian woman to win a medal at ITTF-ATTU Asian Cup Bangkok, Thailand in 2022?
(a) Ankita Das (b) Neha Aggarwal
(c) Manika Batra (d) Mouma Das

2. Which football player has become the first male player to score in five World Cup ?
(a) Antonio Carbajal (b) Lothar Matthaus
(c) Lionel Messi (d) Cristiano Ronaldo

3. Who has created three new national records in the 40kg weight category at the Khelo India National Ranking Women's Weightlifting Tournament ?
(a) Akanksha Vyavahare
(b) Mirabai Chanu
(c) Lalchhanhimi (d) Yogita Khedkar.

4. Who has won the titles in the Open men's section in "Asian Continental Chess Championship" ?
(a) GM R Praggnanandhaa
(b) GM Magnus Carlsen
(c) GM Fabiano Caruana
(d) GM B. Adhiban

5. Which country has won gold medal in Asian Squash Team Championships in 2022?
(a) Hong Kong (b) India
(c) Malaysia (d) Kuwait

6. Who has become the first player from India to get elected in the Athletes' Commission of the International Table Tennis Federation (ITTF)?
(a) Sathiyan Gnanasekaran
(b) Achanta Sharath Kamal
(c) Somyajit Ghosh
(d) Amalraj Anthony Arputharaj

7. Who is the first woman referee to take charge on men's FIFA World Cup ?
(a) Yoshimi Yamashita (b) Stephanie Frappart
(c) Salima Mukansanga (d) Kathryn Nesbitt

8. Which country has won the Davis Cup in 2022?
(a) Russia (b) Croatia
(c) Australia (d) Canada

9. In which stadium FIFA World Cup 2022 final will be held?
(a) Al Khor Stadium
(b) Khalifa International Stadium
(c) Lusail Stadium
(d) Al Wakrah Stadium

10. Ms Ashwini Akkunji C. who was recently seen in news, is a famous sportsperson of which event?
(a) Weightlifting (b) Table Tennis
(c) Badminton (d) Athletics

Answer Key

1.	(c)	**2.**	(d)	**3.**	(a)	**4.**	(a)	**5.**	(b)
6.	(b)	**7.**	(b)	**8.**	(d)	**9.**	(c)	**10.**	(d)

◆ ◆

CLASS-XII

BRUSH UP for NEET/JEE

Brush up your concepts to get high rank in NEET/JEE (Main and Advanced) by reading this column. This specially designed column is updated year after year by a panel of highly qualified teaching experts well-tuned to the requirements of these Entrance Tests.

Unit 5 E.M. Waves | Optics

E.M. Waves

In 1865, Maxwell discovered the displacement current and after this discovery, he predicted the transmission of energy by electromagnetic waves, which could travel with the speed of light. This led him to conclude that light itself is an electromagnetic wave.

ELECTROMAGNETIC WAVES

Displacement Current

- Maxwell assumed that a current also flows in the gap between the two plates of a capacitor, during the process of charging, known as displacement current I_D. This displacement current originates due to time varying electric field between the plates of capacitor and is given by $I_D = \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$
  where ϕ_ε is the electric flux linked with the space between the two plates of the capacitor.
- Using the concept of displacement current I_D, Ampere's circuital law can be modified as
  $\oint \vec{B}\cdot d\vec{l} = \mu_0(I_C + I_D)$
- Maxwell's equations:
  - $\oint \vec{E}\cdot d\vec{A} = \frac{q}{\varepsilon_0}$ (Gauss's law for electricity)
  - $\oint \vec{B}\cdot d\vec{A} = 0$ (Gauss's law for magnetism)
  - $\oint \vec{E}\cdot d\vec{l} = -\frac{d\phi_B}{dt}$ (Faraday's law)
  - $\oint \vec{B}\cdot d\vec{l} = \mu_0 I_C + \mu_0\varepsilon_0 \frac{d\phi_E}{dt}$ (Ampere-Maxwell law)

Nature of Electromagnetic Waves

- Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, $\vec{E}$ and $\vec{B}$ are perpendicular to each other, and to the direction of propagation of the electromagnetic wave.
- For a wave of frequency υ, wavelength λ and propagating along z-direction, we have

$$E = E_x(t) = E_0 \sin(kz - \omega t)$$

$$= E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \upsilon t\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

$$B = B_y(t) = B_0 \sin(kz - \omega t)$$

$$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \upsilon t\right)\right]$$

$$= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right]$$

  They are related by $E_0/B_0 = c$.
- The speed of light, in free space, is related to μ_0 and ε_0 (the free space permeability and permittivity constants) as : $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$.
- The speed of light or an electromagnetic wave in a material medium is given by $v = \frac{1}{\sqrt{\mu\varepsilon}}$ where μ is the permeability of the medium and ε its permittivity.

Optics

Optics is the branch of physics that studies the phenomena and laws associated with the generation, propagation and interaction of light with substances. Here, we will deal with five important properties of light namely reflection, refraction, interference, diffraction and polarisation.

Ray Optics

Ray optics treats the law of propagation of light in a transparent media on the basis of notions of light as a combination of light-rays-lines along which energy of electromagnetic waves propagates.

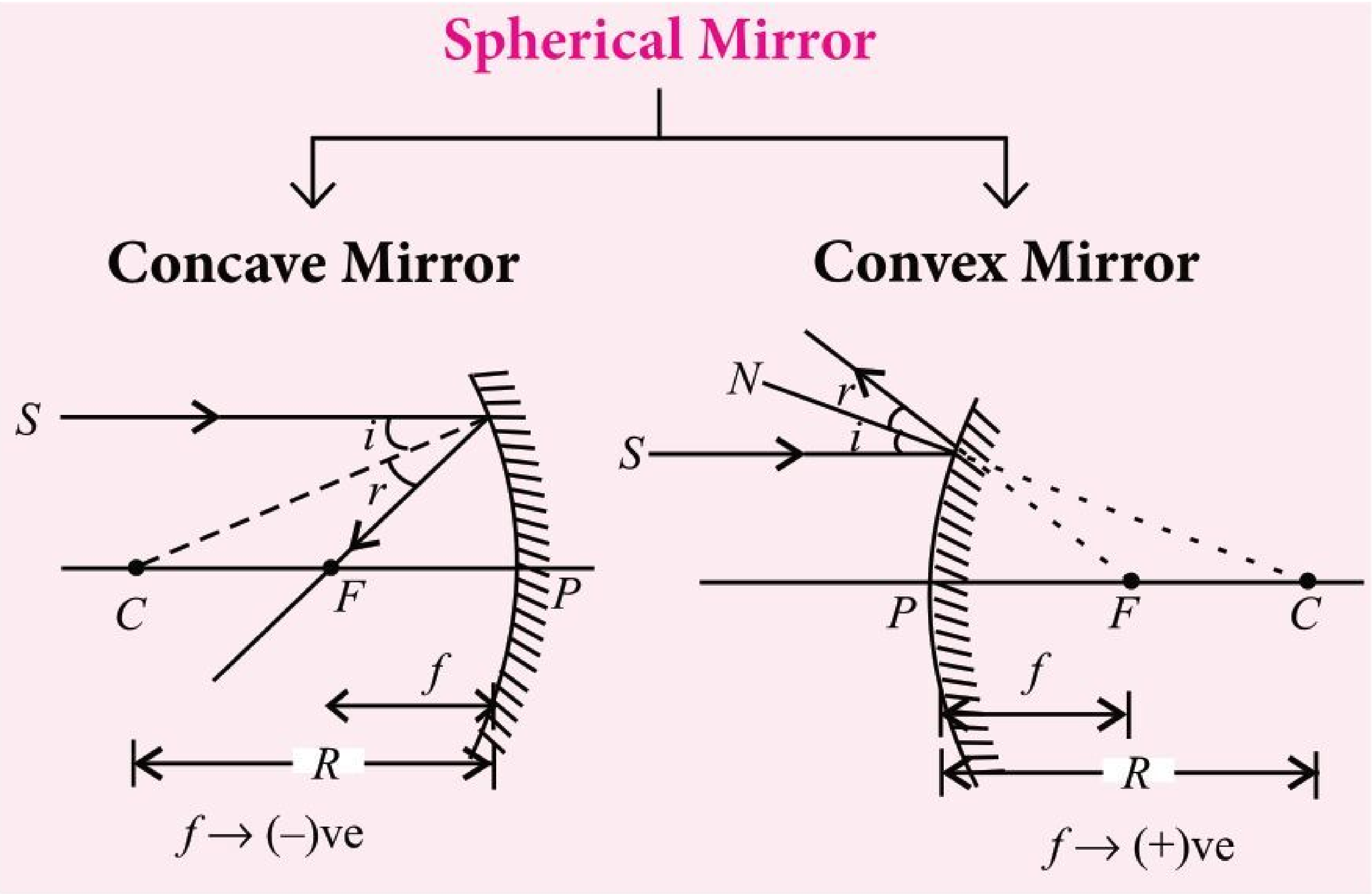
Reflection

If the incident light after interacting with a boundary separating the two media comes back in the same medium, the phenomenon is called reflection and the boundary is known as reflector.

Laws of Reflection

- Angle of incidence ($\angle i$) is equal to the angle of reflection ($\angle r$).
- The incident ray, the reflected ray and the normal, all lie in the same plane.

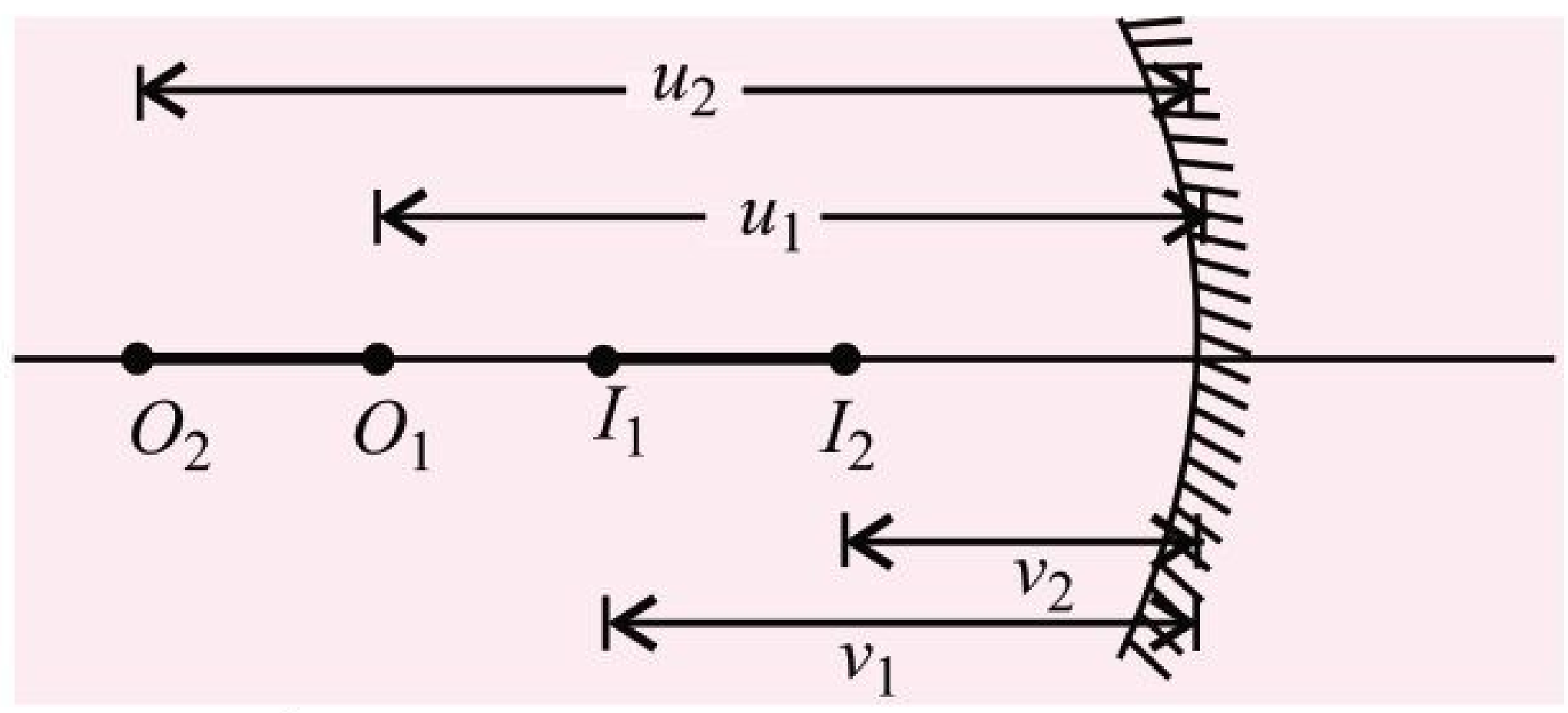
Reflection through Spherical Surfaces


Spherical Mirror
Concave Mirror
Convex Mirror
S
i
r
C
F
P
f
R
$f \rightarrow (-)$ve
N
r
S
i
P
F
C
f
R
$f \rightarrow (+)$ve

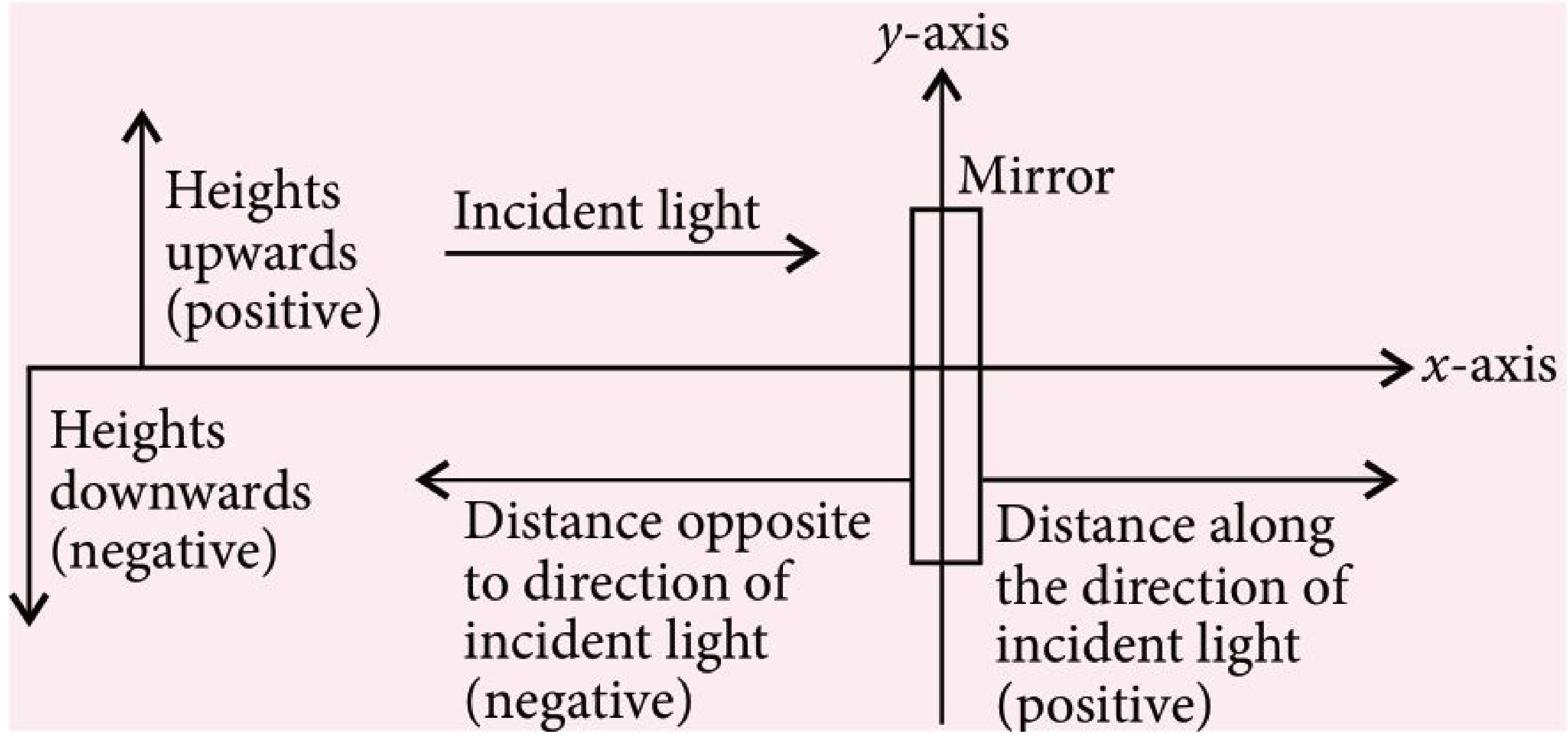
- Focal length $f = R/2$
- Mirror formula, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$
- Lateral magnification,

$$m = \frac{h_i}{h_0} = \frac{-v}{u} = \frac{f}{f-u} = \frac{f-v}{f}$$

- Longitudinal Magnification
  - For large object (O_1O_2) : $m_l = \frac{|v_1| - |v_2|}{|u_2| - |u_1|}$
  - For very small object : $m_l = \frac{dv}{du} = \frac{-v^2}{u^2} = -m^2$


u_2
u_1
O_2
O_1
I_1
I_2
v_2
v_1

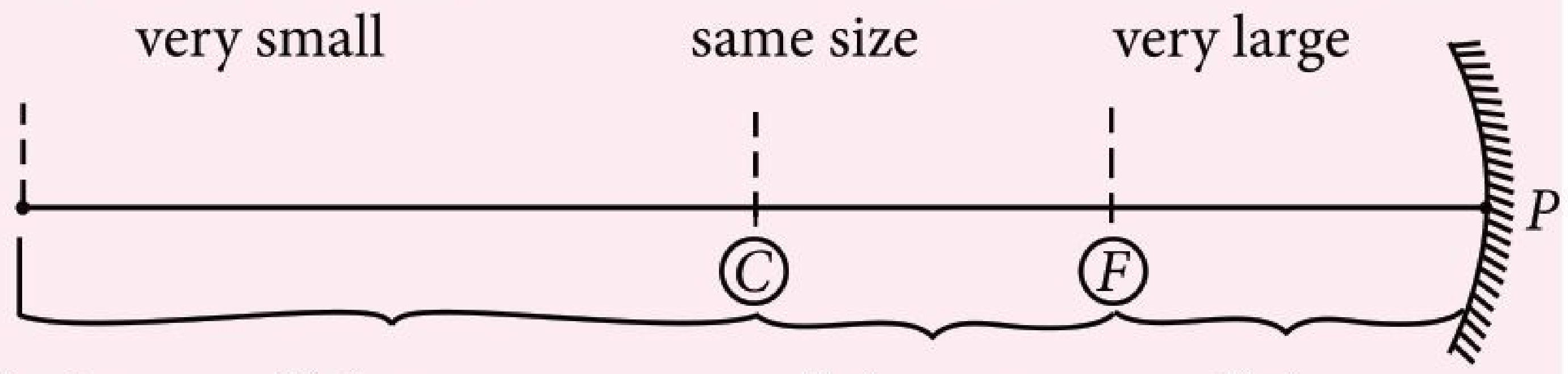
- Sign convention


y-axis
Heights upwards (positive)
Incident light
Mirror
x-axis
Heights downwards (negative)
Distance opposite to direction of incident light (negative)
Distance along the direction of incident light (positive)

Characteristics of Image

- **Concave mirror**

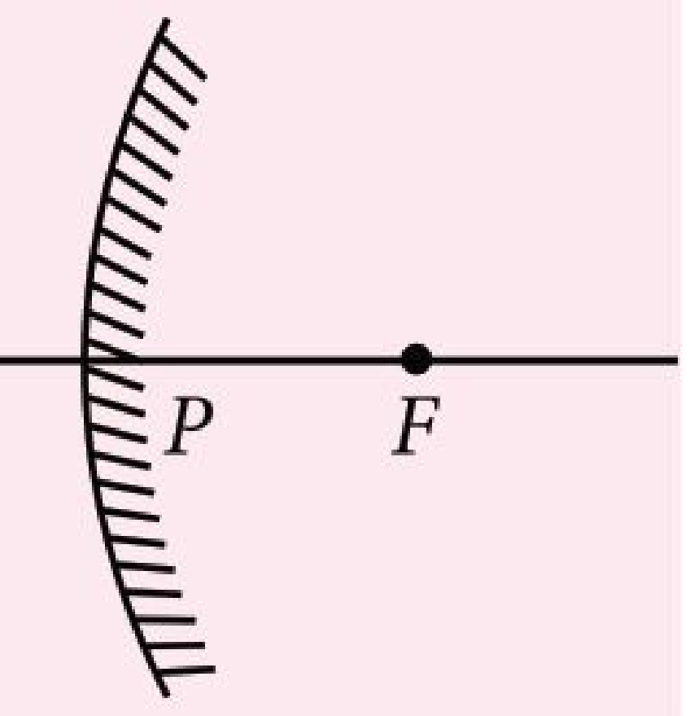
Object :	$u = \infty$	$u = R = 2f$	$u = f$
Image :	Image at F	Image at C	Image at ∞
Nature :	Real, inverted very small	Real, inverted same size	Real, inverted very large



Object :	Between ∞ and C $u > R$	Between F and C $R < u < f$	Between F and P $u < f$
Image :	Between F and C	Between C and ∞	Behind mirror
Nature :	Real, inverted, small	Real, inverted, enlarged	Virtual, upright, enlarged

- **Convex mirror**

Object : $u = \infty$
Image : Image at F
Nature : Virtual, erect, very small



Object : For all position (P to ∞)
Image : Between F and P
Nature : Virtual, erect, small

Refraction

When light passes obliquely from one transparent medium to another, the direction of its path may change at the interface of the two media. This phenomenon is known as refraction of light.

Laws of refraction

- The incident ray, the normal to the interface at the point of incidence and the refracted ray, all lie in the same plane.
- **Snell's law :** The ratio of the sine of the angle of incidence to the sine of the angle of refraction is always a constant (a different constant for a different set of media).

  i.e., $\frac{\sin i}{\sin r} = \text{constant} = \mu_{21}$
- The refractive index of a medium for a light of given wavelength may be defined as the ratio of the speed of light in vacuum to its speed in that medium.

  $$\mu = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}} = \frac{c}{v}$$

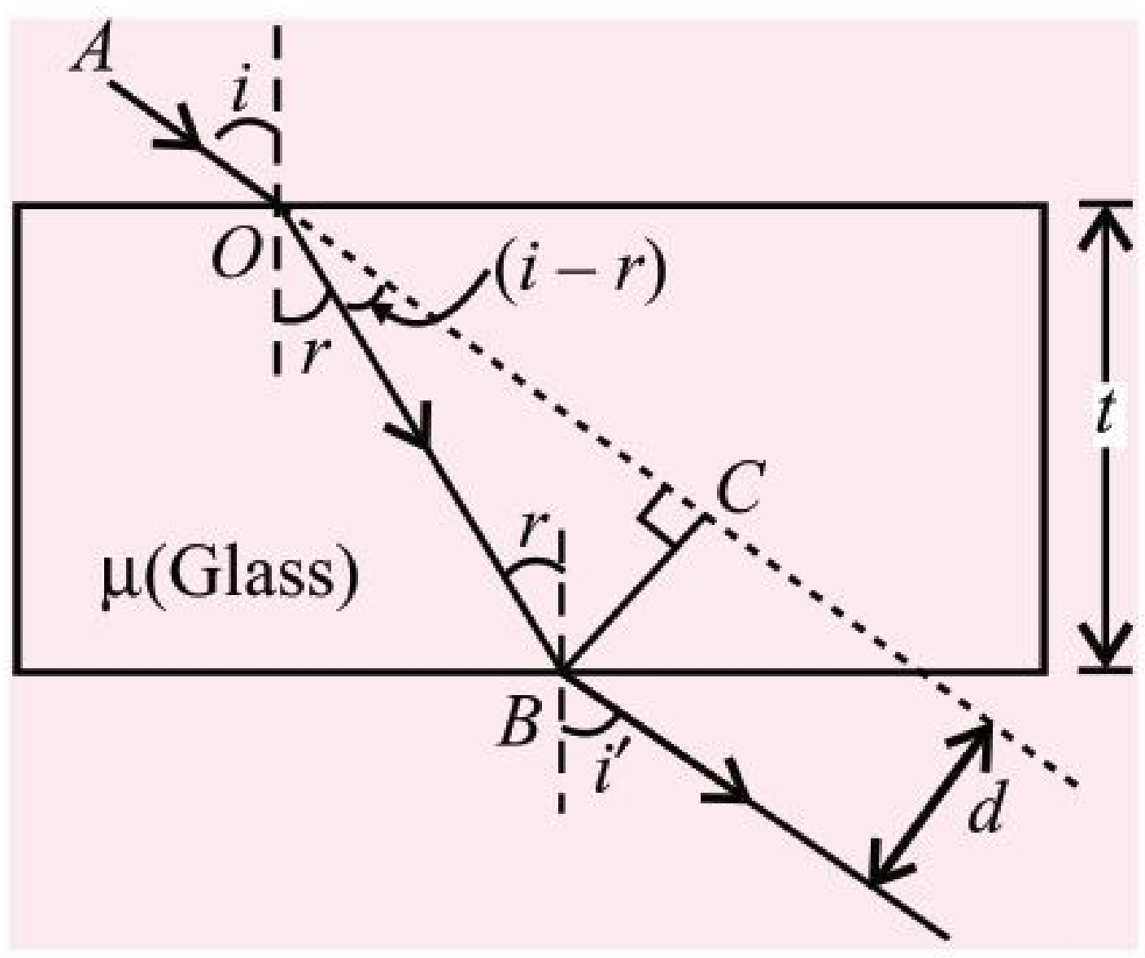
Refraction through a Glass Slab

- Lateral shift in rectangular glass slab,

  $d = BC = OB \sin(i - r)$

  $= \frac{t}{\cos r} \sin(i - r)$

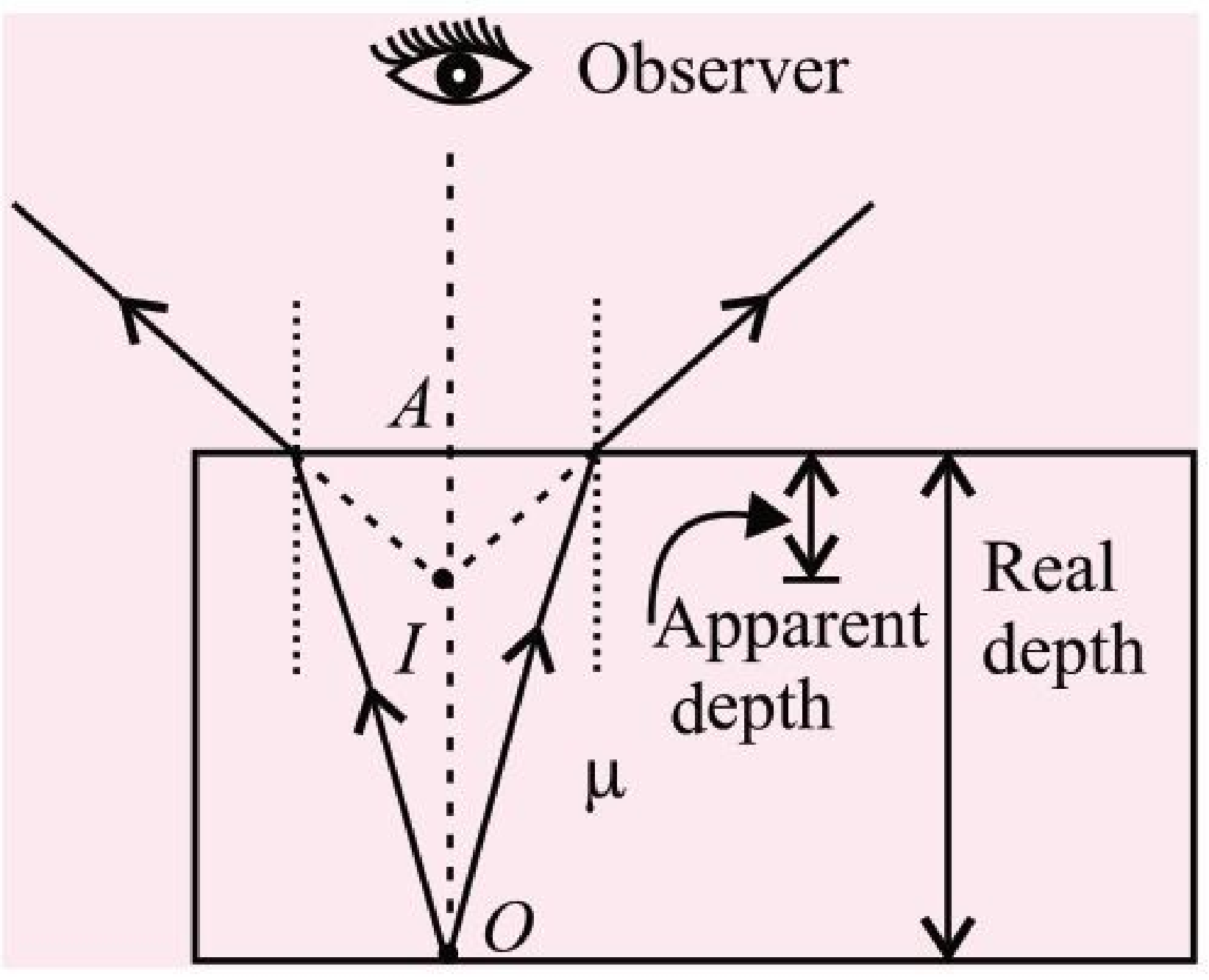
  $\therefore \quad d = t\frac{\sin(i-r)}{\cos r}$



- Apparent depth

  $$= \frac{\text{Real depth}}{\text{Refractive index}\,(\mu)}$$

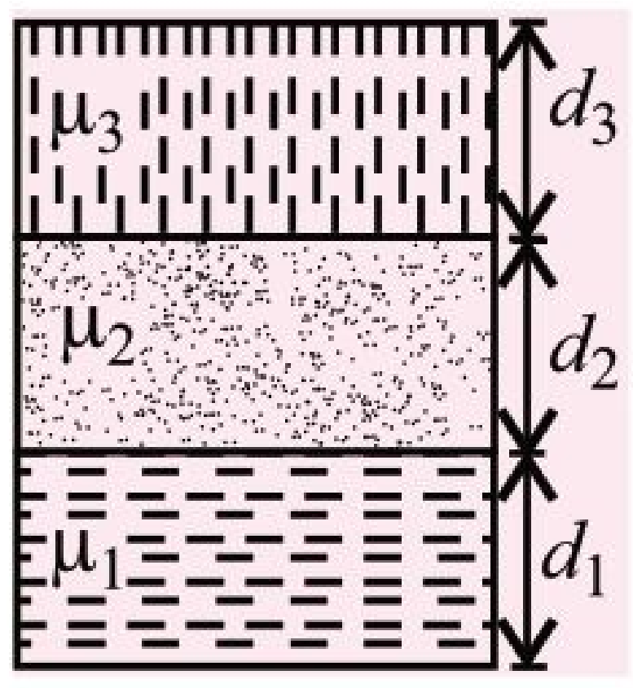
  $AI = \frac{AO}{\mu}$ or $AO = \mu \times AI$



- If there is an ink spot at the bottom of the glass slab of thickness t, it appears to be raised by a distance,

  d = thickness – apparent depth

  $$= t - \frac{t}{\mu} = t\left(1 - \frac{1}{\mu}\right)$$



- Apparent depth of the container shown in the figure is

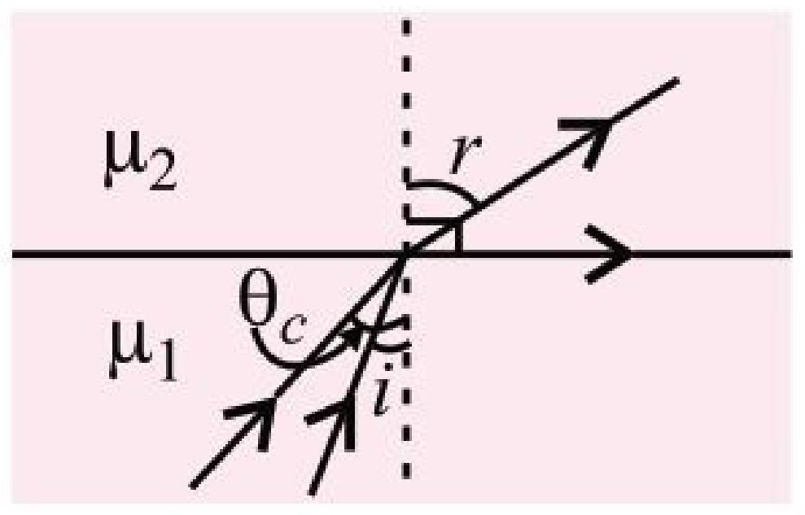
  $$= \frac{d_1}{\mu_1} + \frac{d_2}{\mu_2} + \frac{d_3}{\mu_3}.$$

Total Internal Reflection (TIR)

- Conditions for total internal reflection to take place.
  - Light must travels from denser medium to rarer medium ($\mu_1 > \mu_2$)
  - Angle of incidence at the interface must be greater than the critical angle for the pair of media ($i > \theta_c$).
  - Using Snell's law,

    $\mu_1 \sin\theta_c = \mu_2 \sin 90° = \mu_2$

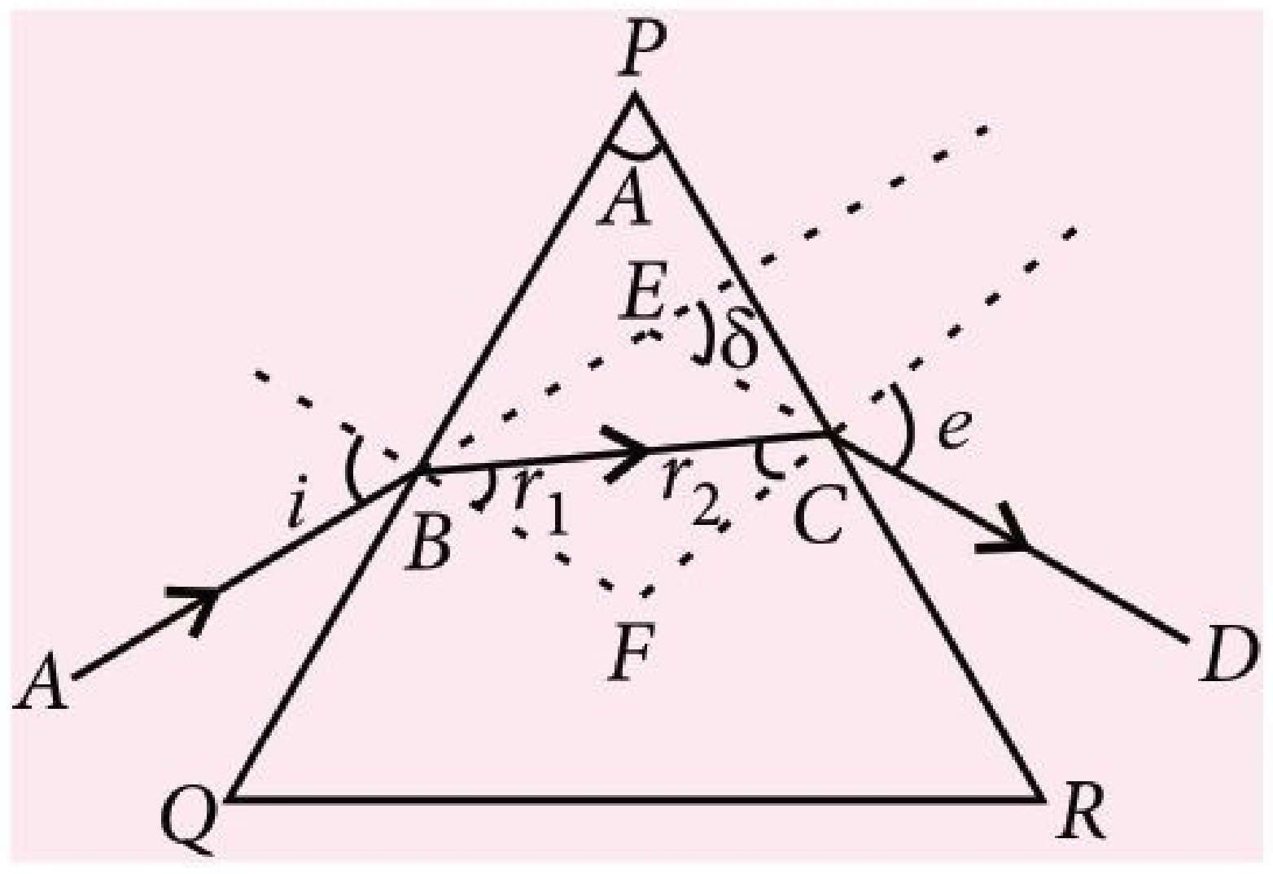
    $$\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)$$



Refraction through a Glass Prism

- Angle of deviation, $\delta = (i - r_1) + (e - r_2) = i + e - A$
- Angle of minimum deviation occurs at $i = e$. Also, $r_1 = r_2 = A/2$

  $\therefore \quad \delta_m = 2i - A$



- Refractive index of prism,

  $$\mu = \frac{\sin\left(\frac{A + \delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$
- If A and δ_m are small, then $\delta_m = (\mu - 1)A$

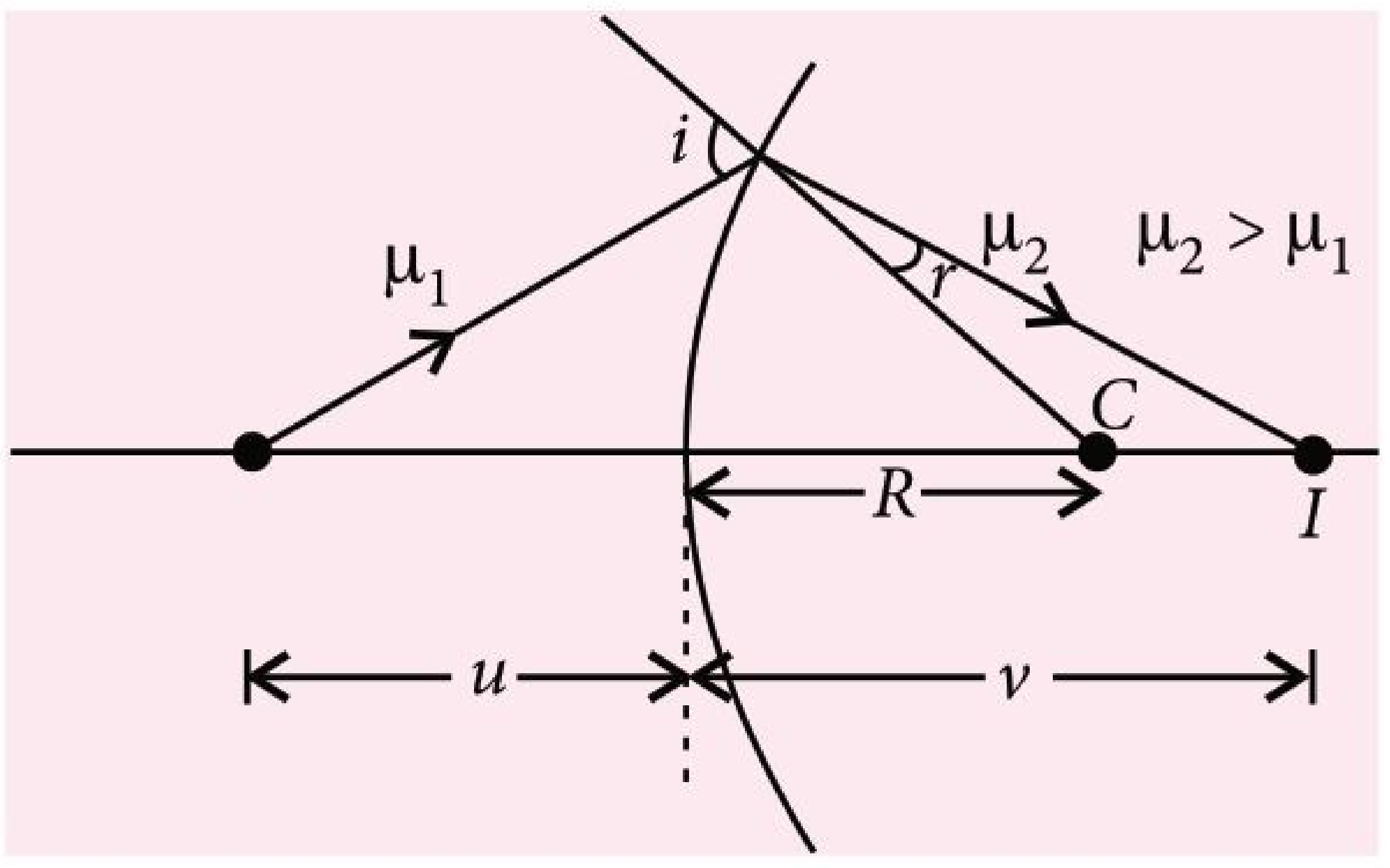
Dispersion : Splitting of Light

- Refractive index of a material depends slightly on the wavelength of light, $\mu = \mu_0 + \frac{A}{\lambda^2}$; This is Cauchy's formula.
- Deviation of violet, yellow and red light are $\delta_v = (\mu_v - 1)A$; $\delta_y = (\mu_y - 1)A$, $\delta_r = (\mu_r - 1)A$

  δ_y is also known as average deviation.
- Angular dispersion, $\theta = \delta_v - \delta_r = (\mu_v - \mu_r)A$
- Dispersive power of the medium, $\omega = \frac{\theta}{\delta_y} = \frac{\mu_v - \mu_r}{\mu_y - 1}$
  - It depends only on prism material.

Refraction at Transparent Spherical Surfaces

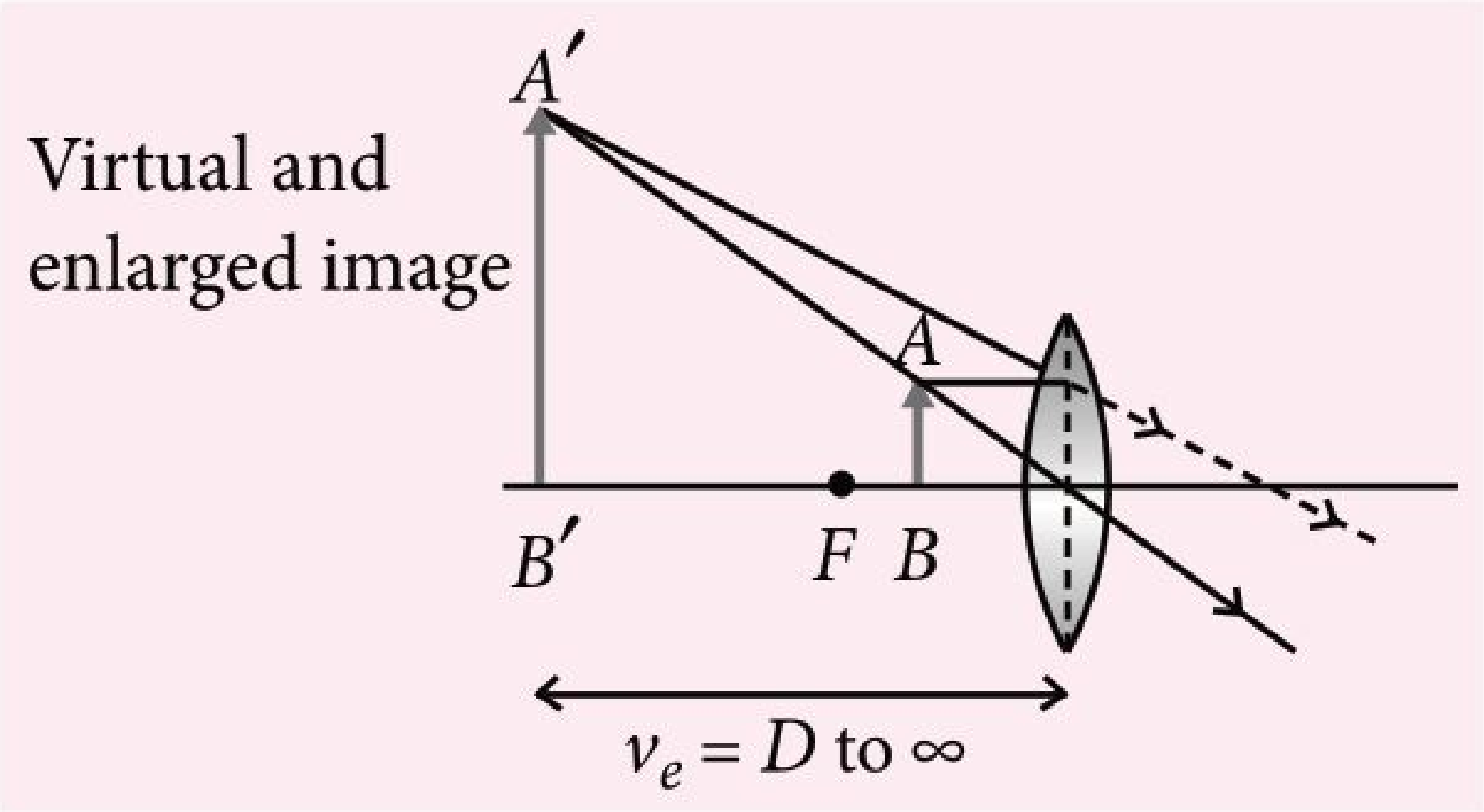
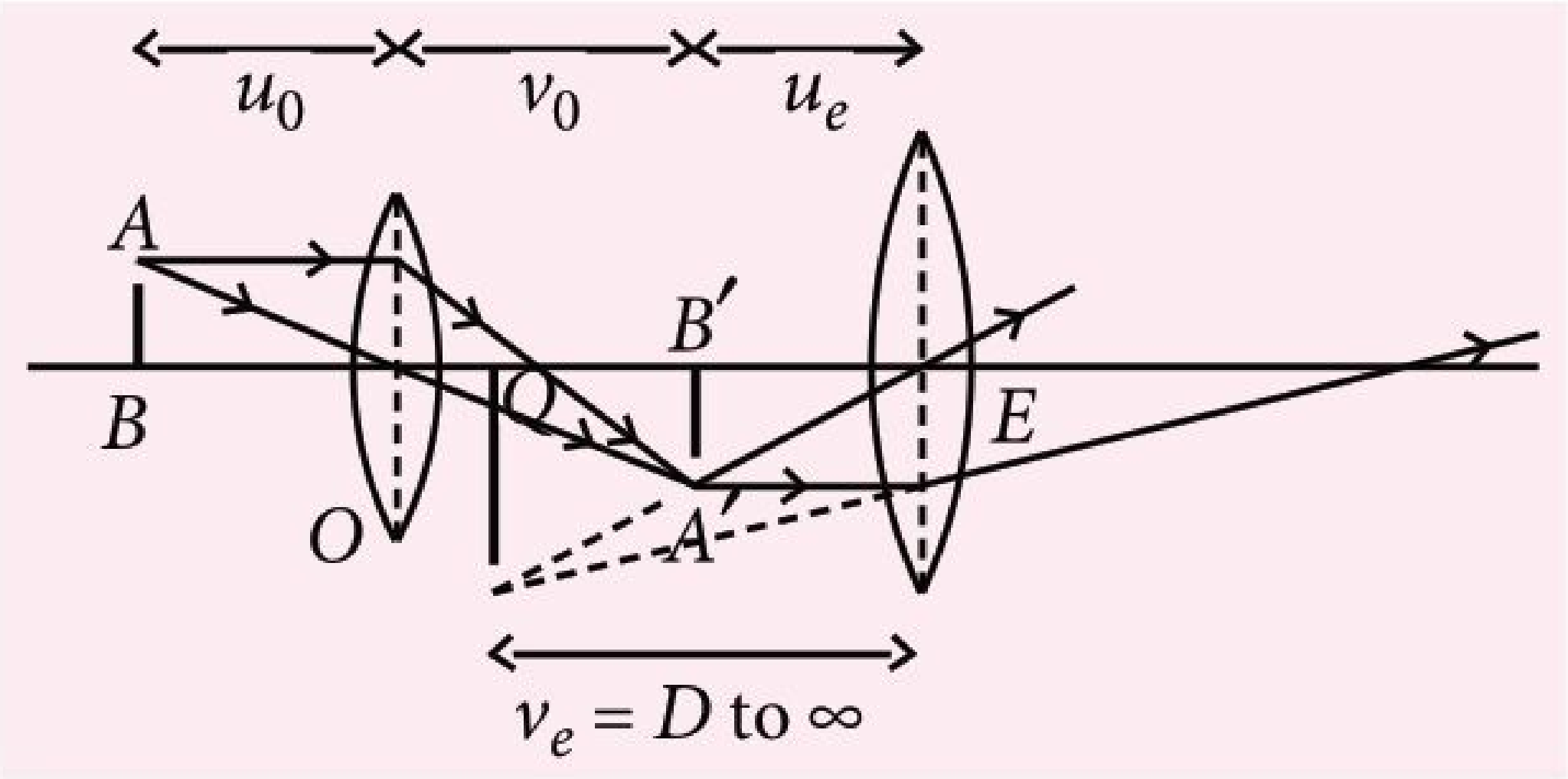
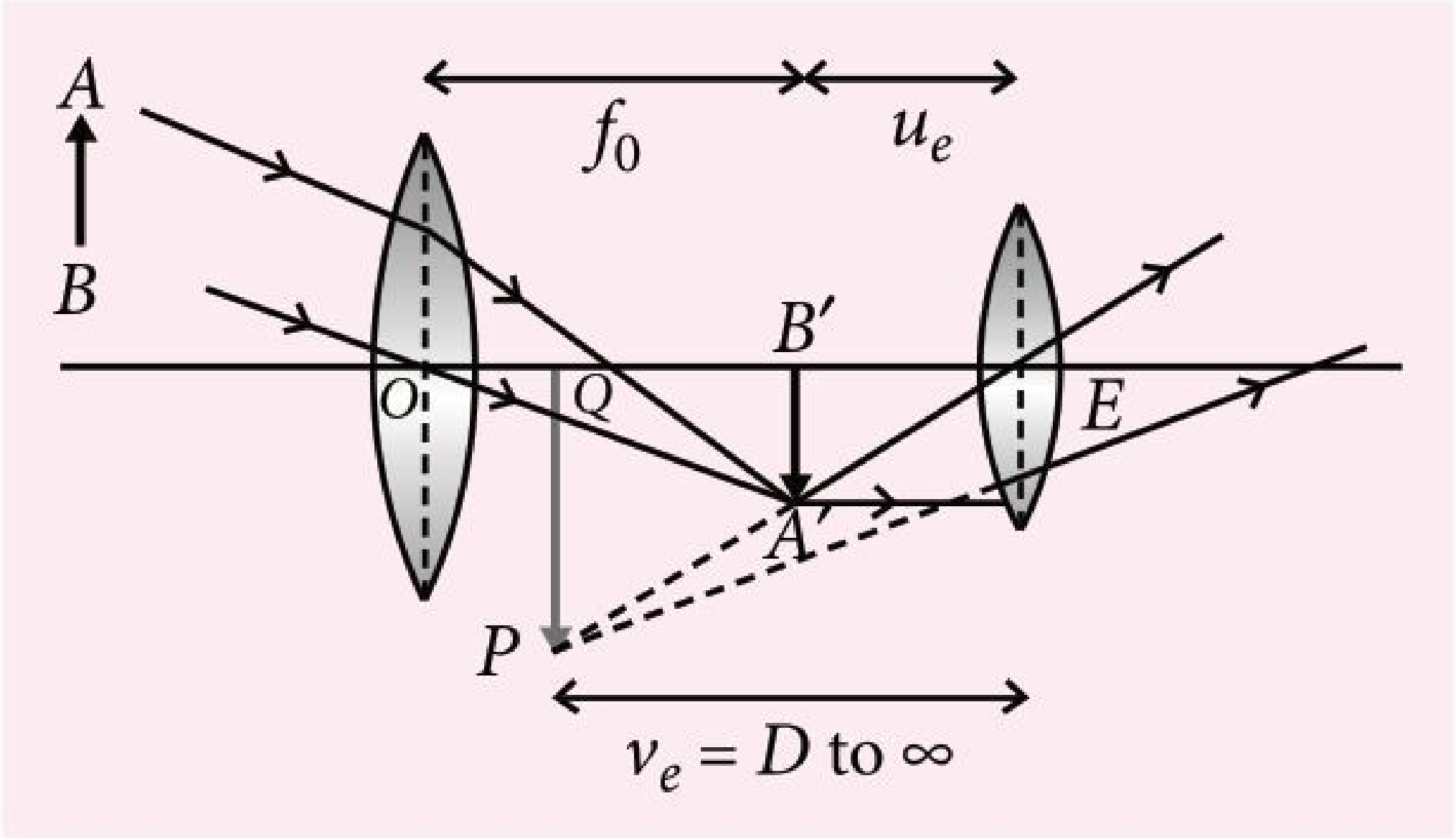
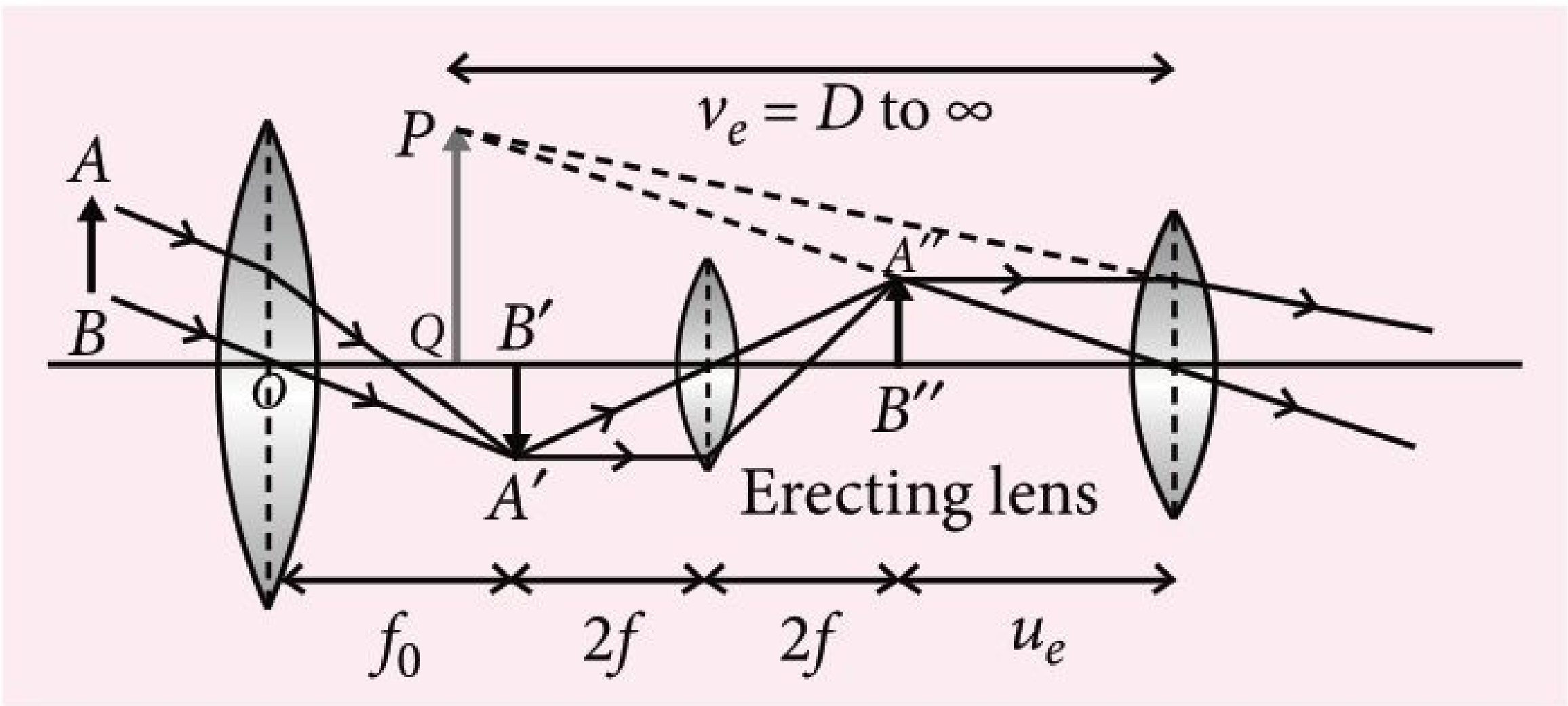
- Standard result : $\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$
- This formula is valid for any curved spherical surface.

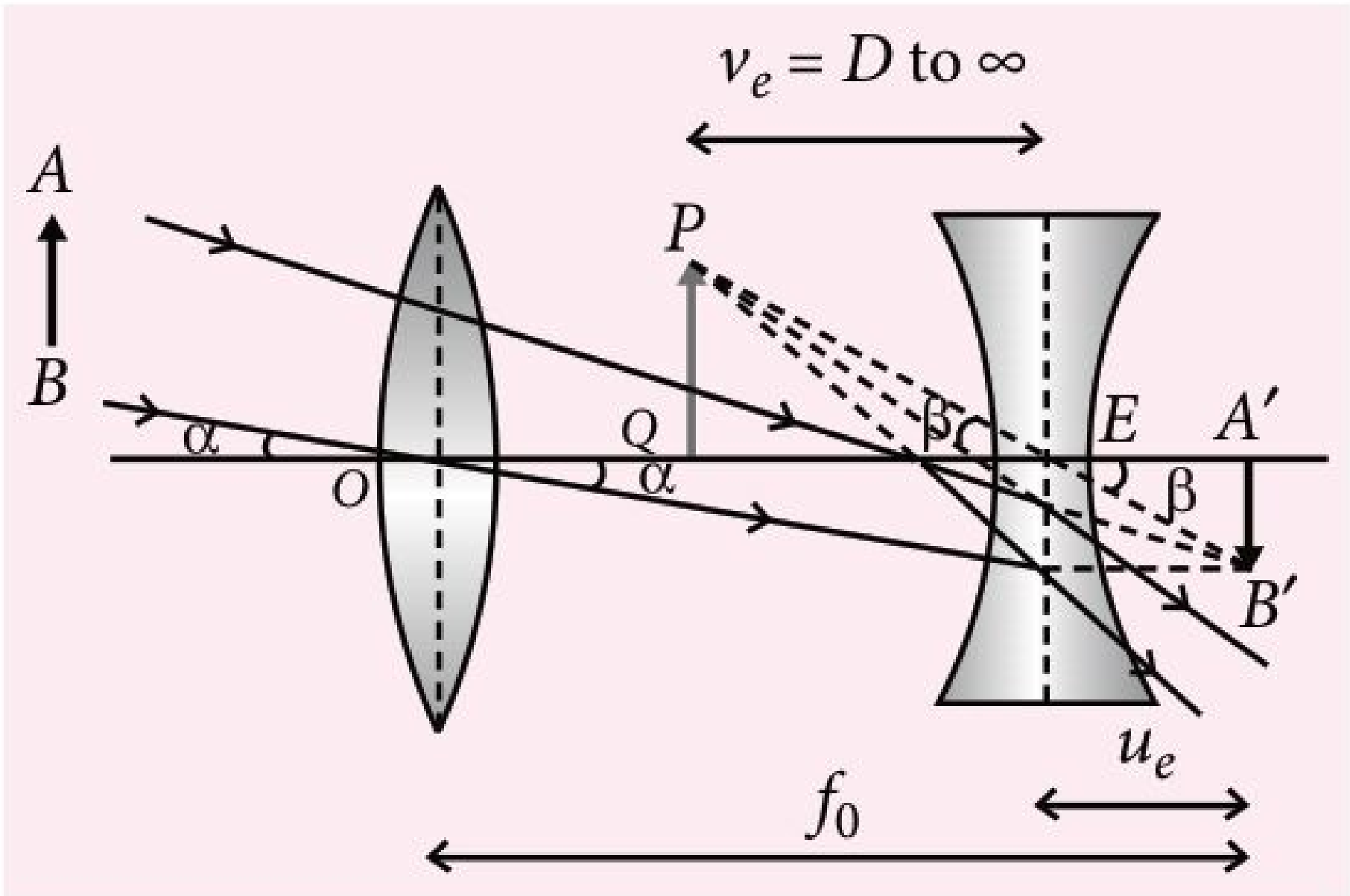
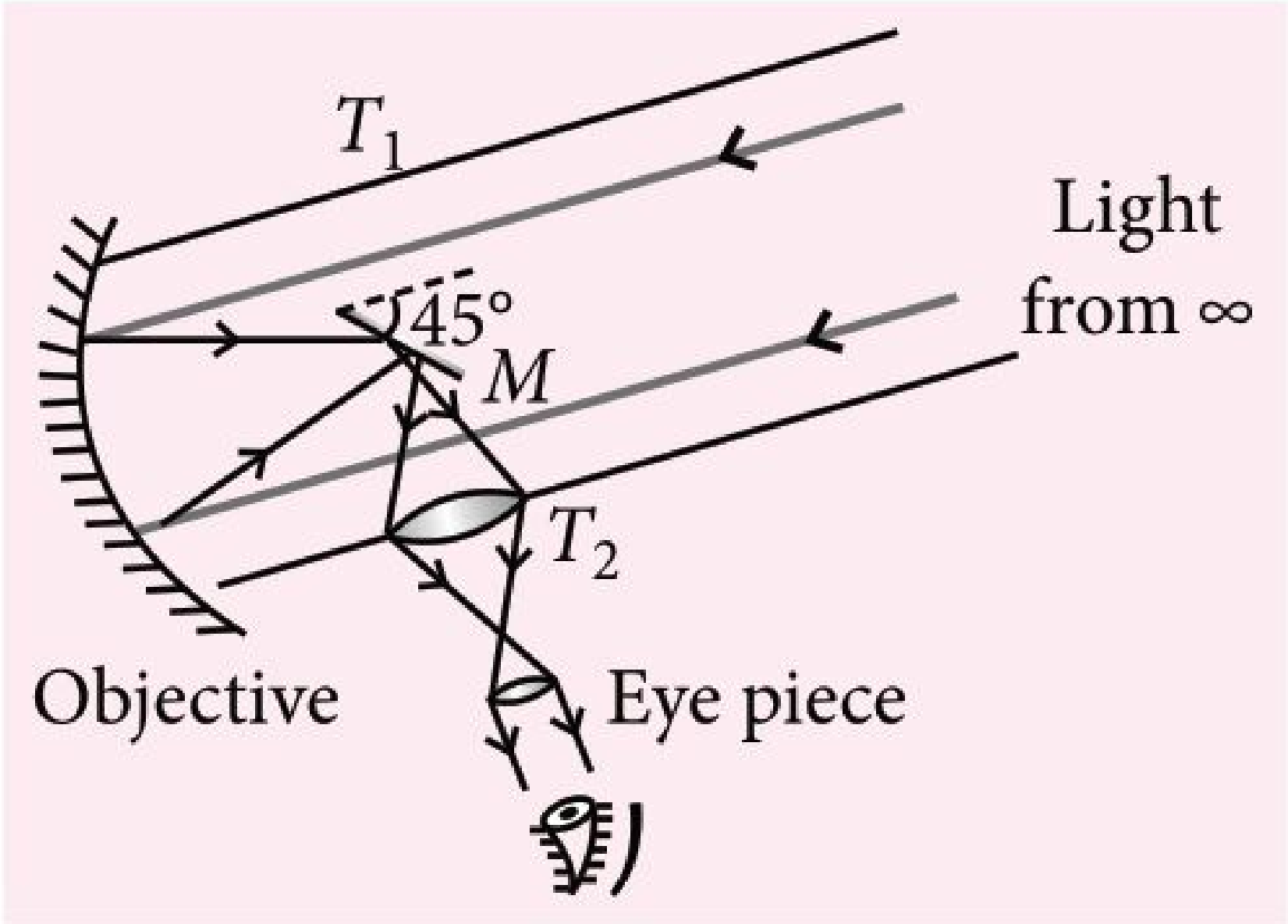

i
r
μ_1
μ_2
$\mu_2 > \mu_1$
C
R
I
u
v

- If refracting surface is plane then $R = \infty$.
- $\frac{\mu_2}{v}-\frac{\mu_1}{u}=0$ or $\frac{u}{v}=\frac{\mu_1}{\mu_2}$ or $\frac{\text{Actual distance}}{\text{Apparent distance}}=\frac{\mu_1}{\mu_2}$
- Lens maker's formula, $\frac{1}{f}=\left(\frac{\mu_2}{\mu_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$
- Thin lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$;

  Power of a lens, $P=\frac{1}{f(\text{m})}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$.

Optical Instruments

Optical Instruments	Schematic Representation	Magnification
Simple Microscope	 Virtual and enlarged image A′ A B′ F B $v_e = D$ to ∞	(i) for final image at D $m_D=\left(1+\frac{D}{f}\right)$ (ii) for final image at ∞ $m_\infty=\frac{D}{f}$
Compound Microscope	 u_0 v_0 u_e A B O Q B′ A′ E $v_e = D$ to ∞	(i) for final image at D $m_D=-\frac{L}{f_0}\left(1+\frac{D}{f_e}\right)$ (ii) for final image at ∞ $m_\infty=-\frac{v_0}{u_0}\times\left(\frac{D}{f_e}\right)$
Astronomical Telescope (Refracting type)	 A B f_0 u_e O Q B′ A′ E P $v_e = D$ to ∞	(i) for final image at D $m_D=-\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ $L_D=f_0+u_e$ (ii) for final image at ∞ $m_\infty=-\frac{f_0}{f_e}$; $L_\infty=f_0+f_e$
Terrestrial Telescope	 $v_e = D$ to ∞ P A B O Q B′ A′ A″ B″ Erecting lens f_0 2f 2f u_e	(i) for final image at D $m_D=\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$ $L_D=f_0+4f+u_e$ (ii) for final image at ∞ $m_\infty=\left(\frac{f_0}{f_e}\right)$; $L_\infty=f_0+4f+f_e$

Gallilean Telescope	 $v_e = D$ to ∞ A B P α O Q α β C E A′ β B′ u_e f_0	(i) for final image at D $m_D = \frac{f_0}{f_e}\left(1 - \frac{f_e}{D}\right)$ $L_D = f_0 - u_e\,;\, L_\infty = f_0 - f_e$ (ii) for final image at ∞, $m_\infty = \frac{f_0}{f_e}$
Reflecting Telescope	 T_1 45° M T_2 Light from ∞ Objective Eye piece	$m_D = \frac{f_0}{f_e} = \left(\frac{R/2}{f_e}\right)$ R = radius of curvature of concave mirror

Wave Optics

Wavefront

Wavefront is a locus of points which vibrate in same phase. A ray of light is perpendicular to the wavefront.

Wavefronts

- Spherical Wavefront (Point source)
- Cylindrical Wavefront (Thin rod source)
- Plane Wavefront (Parallel beam of light)

Huygen's Principle

Each point on a wavefront acts as fresh source of new disturbance called secondary waves or wavelets. The new wavefront at any later time is given by the forward envelope (tangential surface) in the forward direction of the secondary wavelets at that time. The secondary wavelets spread out in all directions with the speed of light in the given medium.

- **Coherent Sources**
  - Two sources of light which continuously emit light waves of same frequency (or wavelength) with a zero or constant phase difference between them, are called coherent sources.
  - Conditions for obtaining two coherent sources of light.
  - The two sources of light must be obtained from a single source by some method.
  - The two sources must give monochromatic light.
  - The path difference between the waves arriving on the screen from the two sources must not be large.

Interference of Light

If two light waves of the same frequency and having zero or constant phase difference travelling in the same direction then their superposition gets redistributed becoming maximum at some points and minimum at others. This phenomenon is called interference of light.

Addition of Coherent Waves

If A_1, A_2 are the amplitudes of interfering waves due to two coherent sources and ϕ is constant phase difference between the two waves at any point P, then the resultant amplitude at P will be

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$$

Resultant intensity at P is

$$I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$$

- When $\phi = 2n\pi$, where $n = 0, 1, 2, ...$

$$I_{\max} = I_1 + I_2 + 2\sqrt{I_1I_2} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$$

- When $\phi = (2n - 1)\pi$, where $n = 1, 2, 3, ...$

$$I_{\min} = I_1 + I_2 - 2\sqrt{I_1I_2} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$$

$$\frac{I_{\max}}{I_{\min}} = \frac{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2} = \frac{(A_1 + A_2)^2}{(A_1 - A_2)^2}$$

- If the amplitudes of the two waves are equal $A_1 = A_2 = A_0$, then resultant amplitude

  $$A = \sqrt{2A_0^2 + 2A_0^2 \cos\phi} = 2A_0 \cos\left(\frac{\phi}{2}\right)$$

  Resultant intensity, $I = A^2 = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$

  In this case, $A_{\max} = 2A_0$, $I_{\max} = 4I_0$
  $A_{\min} = 0$, $I_{\min} = 0$
  Note : If the sources are incoherent, $I = I_1 + I_2$.

Young's Double Slit Experiment

The phenomenon of interference of light was first observed by a British Physicist Thomas Young. Using two slits illuminated by a monochromatic light source, he obtained alternately bright and dark band on the screen. These bands are called interference fringes or interference bands.

- **Constructive interference :** (*i.e.*, formation of bright fringes)
  - For n^{th} bright fringe,

    Path difference = $n\lambda$ or $d\sin\theta = \frac{dy}{D} = n\lambda$
    d = distance between the two slits
    D = distance of slits from the screen
  - The position of n^{th} bright fringe from the centre of the screen is given by $y_n = n\lambda\frac{D}{d}$
- **Destructive interference :** (*i.e.*, formation of dark fringes)
  - For n^{th} dark fringe,

    path difference = $(2n-1)\frac{\lambda}{2}$
  - The position of n^{th} dark fringe from the centre of the screen is given by

    $$y'_n = (2n-1)\frac{\lambda}{2}\frac{D}{d}$$
- The distance between any two consecutive bright or dark fringes is called fringe width.

  Fringe width, $\beta = \frac{\lambda D}{d}$
  - Angular fringe width, $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$
- Intensity and width ratio, $\frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{A_1^2}{A_2^2}$
- Fringe visibility, $V = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$
- When entire apparatus of Young's double slit experiment is immersed in a medium of refractive index μ, then fringe width becomes

  $$\beta' = \frac{\lambda' D}{d} = \frac{\lambda D}{\mu d} = \frac{\beta}{\mu}$$
- When a thin transparent plate of thickness, t and refractive index, μ is placed in the path of one of the interfering waves, fringe width remains unaffected but the entire pattern shifts by

  $$\Delta y = (\mu - 1)\,t\,\frac{D}{d} = (\mu - 1)\,t\,\frac{\beta}{\lambda}$$

  This shifting is towards the side in which transparent plate is introduced.
  - Number of shifted fringes, $N = \frac{\Delta y}{\beta} = \frac{(\mu - 1)t}{\lambda}$

Interference due to Thin Films

- Interference due to reflected light (reflected system of light)
  - For a bright fringe,

    $2\mu t\cos r = (2n+1)\frac{\lambda}{2}$; where, $n = 0, 1, 2, 3, \ldots$
  - For a dark fringe

    $2\mu t\cos r = n\lambda$; where, $n = 0, 1, 2, 3 \ldots$
- Interference due to transmitted light (transmitted system of light)
  - For a bright-fringe,

    $2\mu t\cos r = n\lambda$; where $n = 0, 1, 2, 3, \ldots$
  - For a dark fringe,

    $2\mu t\cos r = (2n+1)\frac{\lambda}{2}$; where $n = 0, 1, 2, 3, \ldots$
- The conditions for maxima and minima in the reflected system are just opposite to those for the transmitted system. Thus, the reflected and transmitted systems are complimentary *i.e.*, a film which appears bright by reflected light will appear dark by transmitted light and vice-versa.

Diffraction of Light

- The diffraction phenomenon is generally divided into the following two classes :
  - **Fresnel diffraction :** In this case, either the source or the screen or both are at finite distances from the aperture or obstacle causing diffraction.
  - **Fraunhofer diffraction :** In this case, the source and the screen on which the pattern is observed are at infinite distances from the aperture or the obstacle causing diffraction.

Single Slit Diffraction

The diffraction pattern produced by a single slit of width a consists of a central maximum bright band with alternating bright and dark bands of decreasing intensity on both sides of the central maximum.

- Condition for n^{th} secondary maximum is,
  Path difference $= a\sin\theta_n = (2n+1)\dfrac{\lambda}{2}$
  where $n = 1, 2, 3, \ldots\ldots.$
- Condition for n^{th} secondary minimum is,
  Path difference $= a\sin\theta_n = n\lambda$
  where $n = 1, 2, 3, \ldots\ldots.$
- Width of secondary maxima or minima
  $\beta = \dfrac{\lambda D}{a} = \dfrac{\lambda f}{a}$ where, a = width of slit
  D = distance of screen from the slit
  f = focal length of lens for diffracted light
- Width of central maximum $= \dfrac{2\lambda D}{a} = \dfrac{2f\lambda}{a}$
- Angular fringe width of central maximum $= \dfrac{2\lambda}{a}$.
- Angular fringe width of secondary maxima or minima $= \dfrac{\lambda}{a}$

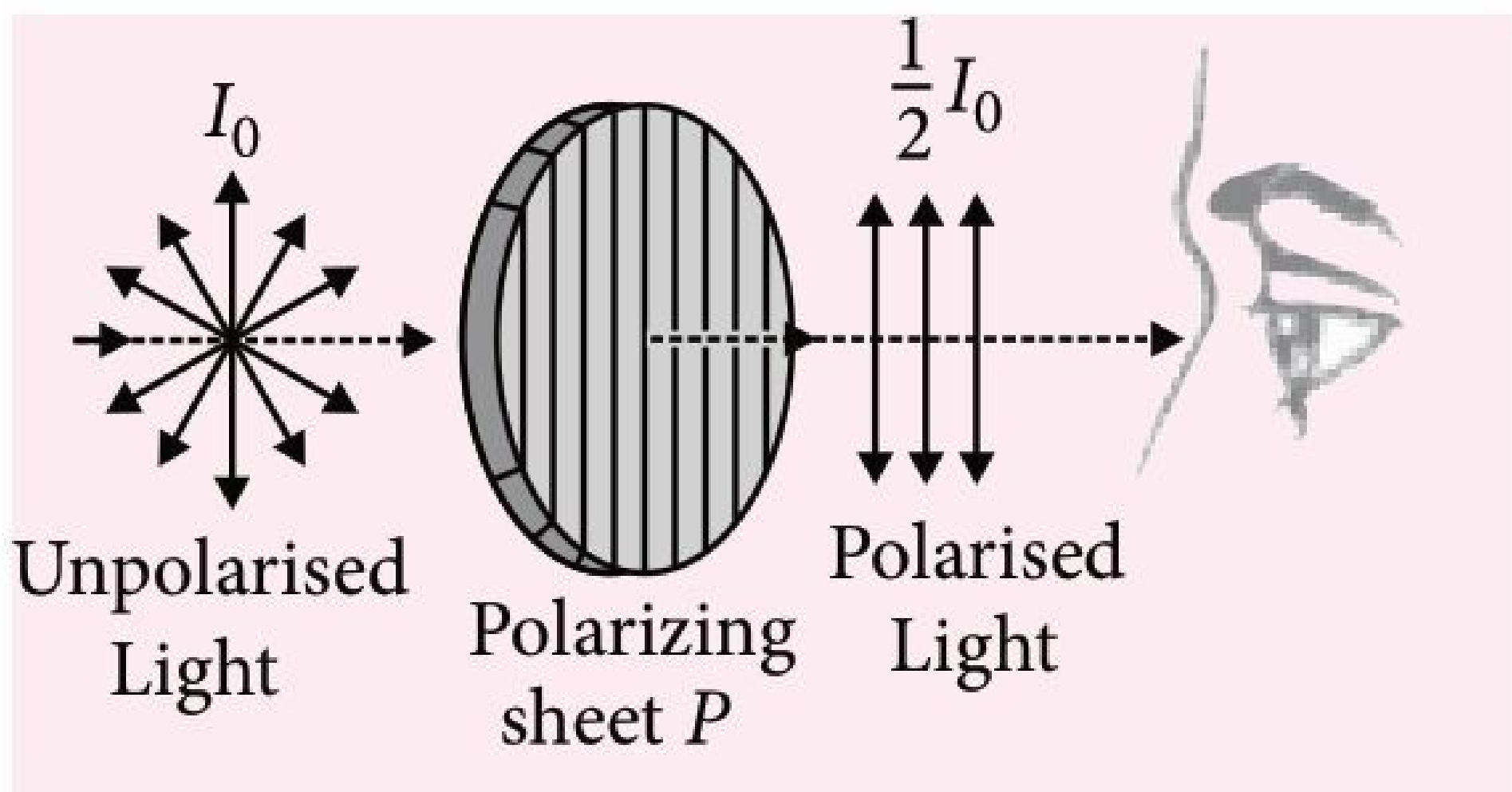
Resolving Power of Optical Instruments

Resolving power is the ability of the instrument to resolve or to see as separate, the images of two close objects.

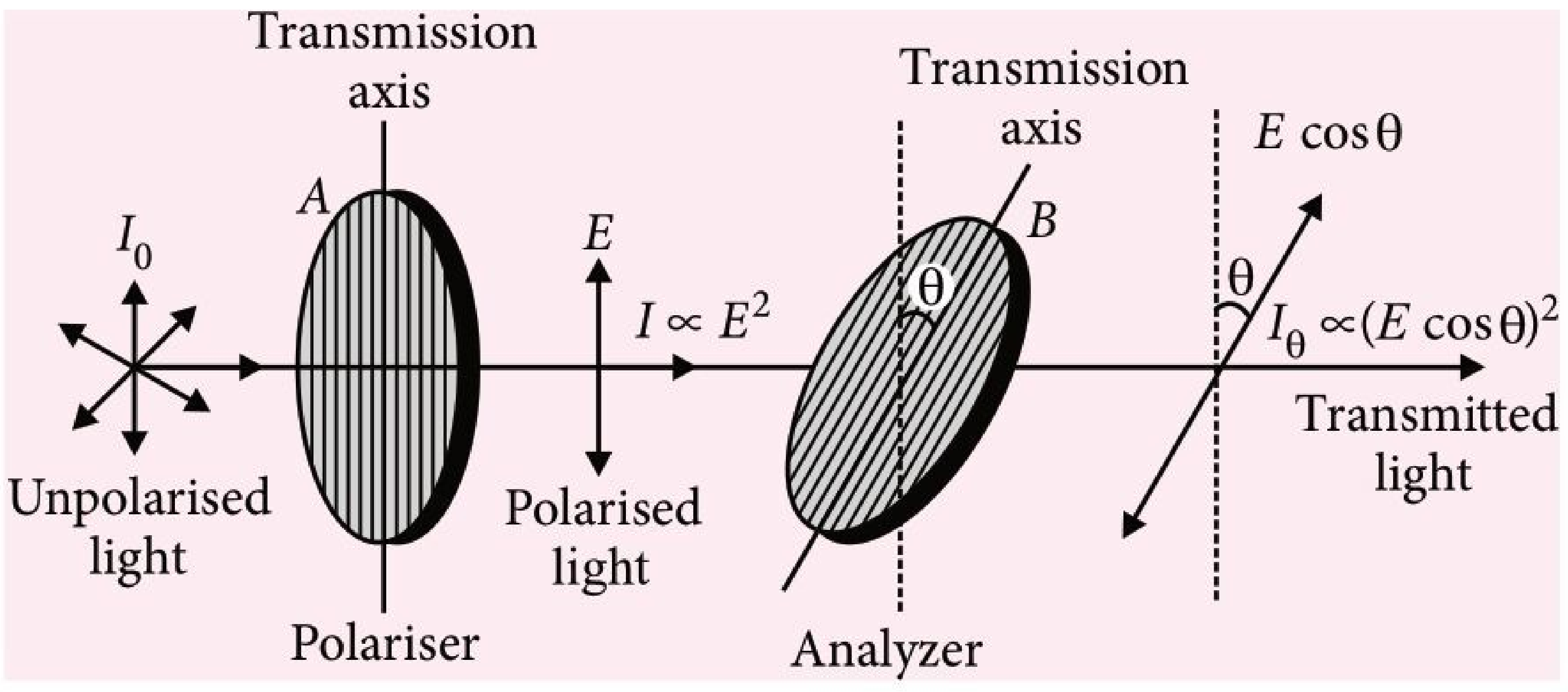
- Resolving power (R) $= \dfrac{1}{\text{Resolving limit}}$
  - Resolving power of microscope,
    $R = \dfrac{1}{\Delta d} = \dfrac{2\mu\sin\theta}{\lambda}$
  - Resolving power of telescope, $R = \dfrac{1}{\Delta\theta} = \dfrac{a}{1.22\lambda}$
    a = diameter of objective lens of the telescope.

Polarisation of Light

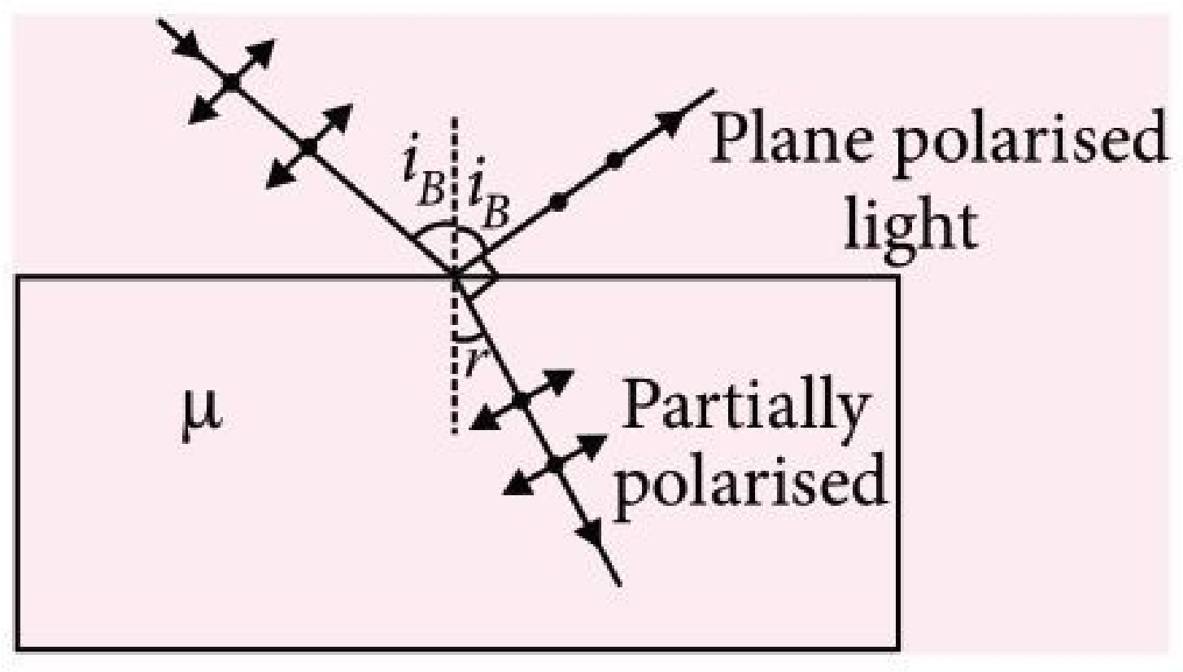
The phenomenon of restricting the vibrations of light (electric vector) in a particular direction, perpendicular to direction of wave motion is called polarisation of light.


I_0
$\frac{1}{2}I_0$
Unpolarised Light
Polarizing sheet P
Polarised Light

- Polarisation of light confirms the transverse nature of light. The plane in which vibrations of polarised light are confined is called plane of vibration. A plane which is perpendicular to the plane of vibration is called plane of polarisation.
- Plane polarised light can be produced by the following methods
  - By reflection
  - By scattering
  - By refraction
  - By dichroism
  - By double refraction
- **Malus's Law :** Intensity of transmitted light by analyser depends on the angle between the polariser and analyser.
  $I_\theta \propto \cos^2\theta \Rightarrow I_\theta = I\cos^2\theta$
  I = intensity of polarised light passing through the polariser.


Transmission axis
A
I_0
E
$I \propto E^2$
Transmission axis
B
θ
$E\cos\theta$
θ
$I_\theta \propto (E\cos\theta)^2$
Transmitted light
Unpolarised light
Polarised light
Polariser
Analyzer

- **Polarisation by reflection (Brewster's law)**
  - When unpolarised light is reflected from a plane boundary between two transparent media, the reflected light is partially polarised. The degree of polarisation depends on the angle of incidence and the ratio of wave speeds in the two media.
  - At polarising angle (Brewster's angle), the reflected and refracted beams are mutually perpendicular to each other.


i_B
i_B
Plane polarised light
μ
r
Partially polarised

$\sin i_B = \mu\sin(r)$
$\sin i_B = \mu\sin(90 - i_B)$
$\Rightarrow\ \mu = \tan i_B$
This is the Brewster's law.

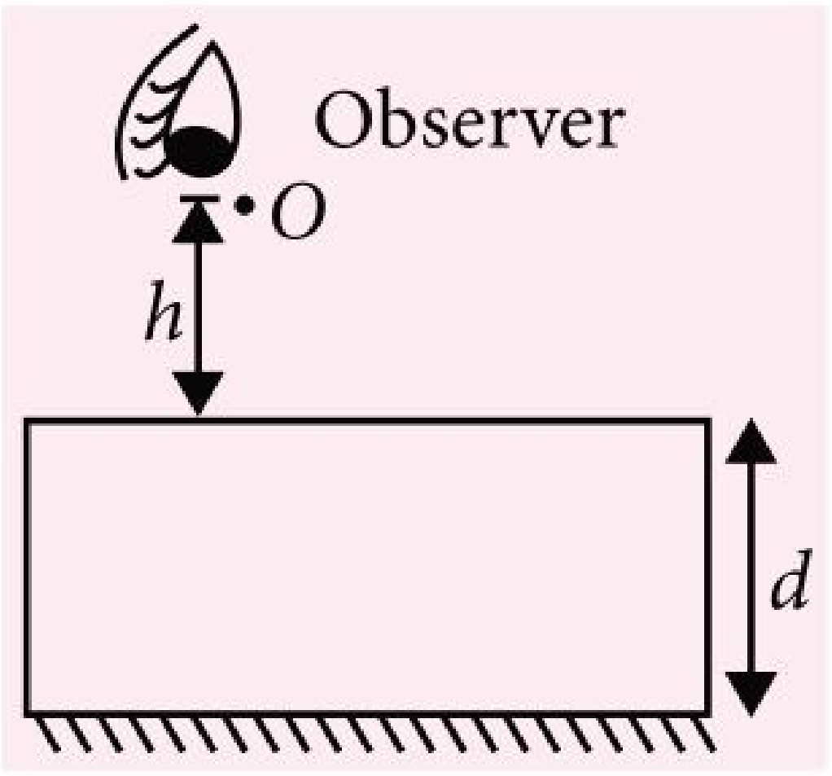
WRAP it up!

1. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 1.5×10^{10} Hz and amplitude 45 V m^{-1}. The amplitude of the oscillating magnetic field and total average energy density of the electromagnetic field of the wave, respectively are
   (a) 1.5×10^{-7}T, 8.91×10^{-9} J m^{-3}
   (b) 2.5×10^{-7}T, 1.6×10^{-9} J m^{-3}
   (c) 1.9×10^{-10}T, 6.6×10^{-7} J m^{-3}
   (d) 4.5×10^{-3}T, 7.8×10^{-9} J m^{-3}

2. A convex lens is made of a material having refractive index 1.25. If it is dipped in water ($\mu = 1.33$), it will behave like a
   (a) convergent lens (b) divergent lens
   (c) a rectangular slab (d) a prism

3. Path difference for the first secondary maximum in the diffraction pattern of a single slit is given by (*a* is the width of the slit)
   (a) $a \sin\theta = \frac{\lambda}{2}$ (b) $a \cos\theta = \frac{3\lambda}{2}$
   (c) $a \sin\theta = \lambda$ (d) $a \sin\theta = \frac{3\lambda}{2}$

4. A point luminous object (*O*) is at a distance *h* from front face of a glass slab of width *d* and of refractive index μ. A reflecting plane mirror is fixed on the back face of slab. An observer sees the image of object in mirror as shown in figure. Distance of image from front face as seen by observer will be



   (a) $h + \frac{2d}{\mu}$ (b) $h + 2d$ (c) $h + d$ (d) $2h + \frac{d}{\mu}$

5. A point source of light is placed at a depth *H* below the surface of water of refractive index μ. A floating opaque disc is placed on the surface of water so that light from the source is not visible from the surface. The minimum diameter of the disc is
   (a) $\frac{2H}{(\mu^2 - 1)^{1/2}}$ (b) $2H(\mu^2 - 1)^{1/2}$
   (c) $\frac{H}{2(\mu^2 - 1)^{1/2}}$ (d) $H(\mu^2 - 1)^{1/2}$

6. Let the refractive index of a denser medium with respect to a rarer medium be μ_{12} and its critical angle θ_C. At an angle of incidence *A* when light is travelling from denser medium to rarer medium, a part of the light is reflected and the rest is refracted and the angle between reflected and refracted rays is 90°. Angle *A* is given by
   (a) $\frac{1}{\tan^{-1}(\sin\theta_C)}$ (b) $\frac{1}{\cos^{-1}(\sin\theta_C)}$
   (c) $\tan^{-1}(\sin\theta_C)$ (d) $\cos^{-1}(\sin\theta_C)$

7. An eye specialist prescribes spectacles having a combination of a convex lens of focal length 50 cm in contact with a concave lens of focal length 25 cm. The power of this lens combination is
   (a) + 1.5 D (b) – 2 D
   (c) + 6.67 D (d) – 6.67 D

8. An electromagnetic wave, going through vacuum is described by $E = E_0 \sin(kx - \omega t)$. Which of the following is independent of wavelength?
   (a) k/ω (b) $k\omega$
   (c) both (a) and (b) (d) neither (a) nor (b).

9. When a thin transparent sheet of refractive index $\mu = \frac{6}{5}$ is placed near one of the slits in Young's double slits experiment, the intensity at the centre of the screen reduces to half of the maximum intensity. The minimum thickness of the sheet should be
   (a) $\frac{\lambda}{4}$ (b) $\frac{5\lambda}{4}$ (c) $\frac{3\lambda}{2}$ (d) $\frac{\lambda}{3}$

10. A diverging lens with magnitude of focal length 20 cm is placed at a distance of 10 cm from a converging lens of magnitude of focal length 15 cm. A beam of parallel light falls on the diverging lens. The final image formed is
    (a) real and at a distance of 30 cm from convergent lens
    (b) virtual and at a distance of 30 cm from convergent lens
    (c) real and at a distance of 30 cm from the divergent lens
    (d) real and at a distance of 5 cm from the convergent lens.

11. An electric field of 300 V m^{-1} is confined to a circular area 10 cm in diameter. If the electric field is increasing at the rate of 40 V $m^{-1}s^{-1}$, the magnitude of magnetic field at a point 12 cm from the centre of the circle will be

(a) 1.85×10^{-15} T (b) 3.70×10^{-16} T
(c) 2.86×10^{-17} T (d) 4.63×10^{-18} T

12. Magnetic field in a plane electromagnetic wave is given by $\vec{B} = B_0 \sin(kx + \omega t)\hat{j}$ T. Expression for corresponding electric field will be (where c is speed of light.)

(a) $\vec{E} = -B_0 c \sin(kx + \omega t)\hat{k}$ V m^{-1}
(b) $\vec{E} = B_0 c \sin(kx - \omega t)\hat{k}$ V m^{-1}
(c) $\vec{E} = \frac{B_0}{c} \sin(kx + \omega t)\hat{k}$ V m^{-1}
(d) $\vec{E} = B_0 c \sin(kx + \omega t)\hat{k}$ V m^{-1}

13. The ratio of resolving powers of an optical microscope for two wavelengths $\lambda_1 = 4000$ Å and $\lambda_2 = 7000$ Å is

(a) 9 : 4 (b) 7 : 4 (c) 16 : 49 (d) 4 : 7

14. Young's double slit experiment is first performed in air and then in a medium other than air. It is found that 9th bright fringe in the medium lies where 5th dark fringe lies in air. The refractive index of the medium is nearly

(a) 0.5 (b) 2.2 (c) 2 (d) 1.25

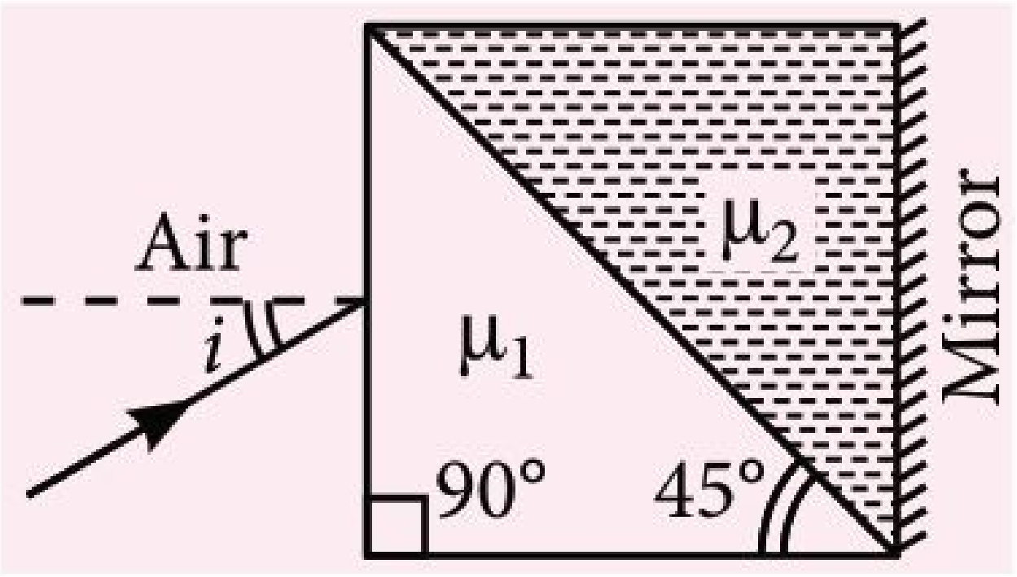
15. A beam of light from a source L is incident normally on a plane mirror fixed at a certain distance x from the source. The beam is reflected back as a spot on a scale placed just above the source L. When the mirror is rotated through a small angle θ, the spot of the light is found to move through a distance y on the scale. The angle θ is given by

(a) $\frac{y}{x}$ (b) $\frac{x}{2y}$ (c) $\frac{x}{y}$ (d) $\frac{y}{2x}$

16. A thin prism having refracting angle 10° is made of glass of refractive index 1.42. This prism is combined with another thin prism of glass of refractive index 1.7. This combination produces dispersion without deviation. The refracting angle of second prism should be

(a) 6° (b) 8° (c) 10° (d) 4°

17. In the given figure, for what value of i, the incidence ray will retrace its initial path?



(a) $\cos^{-1}\left[\mu_1 \sin\left(\frac{\pi}{4} - \sin^{-1}\frac{\mu_2}{\sqrt{2}\mu_1}\right)\right]$

(b) $\sin^{-1}\left[\mu_1 \sin\left(\frac{\pi}{4} - \sin^{-1}\frac{\mu_2}{\sqrt{2}\mu_1}\right)\right]$

(c) $\sin^{-1}\left[\mu_2 \sin\left(\frac{\pi}{4} - \sin^{-1}\frac{\mu_1}{\sqrt{2}\mu_2}\right)\right]$

(d) $\cos^{-1}\left[\mu_2 \sin\left(\frac{\pi}{4} - \sin^{-1}\frac{\mu_1}{\sqrt{2}\mu_2}\right)\right]$

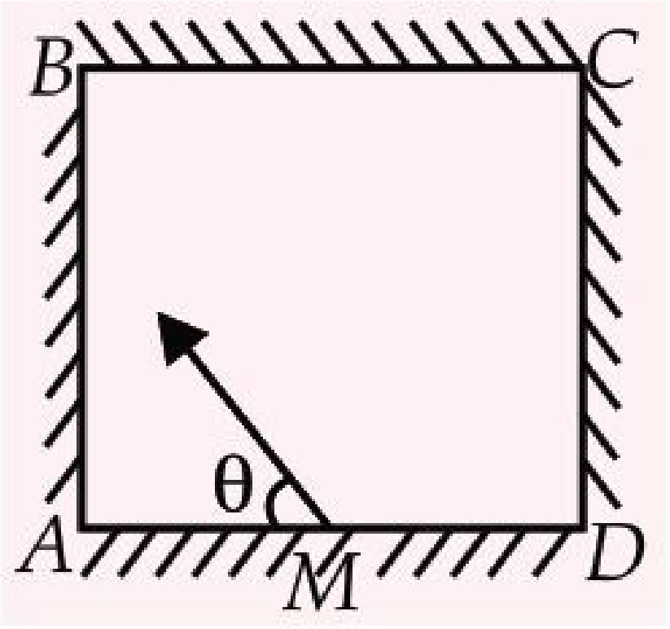
18. In a Young's double slit experiment, slits are separated by 0.5 mm and the screen is placed 150 cm away. A beam of light consisting of two wavelengths, 600 nm and 480 nm, is used to obtain interference fringes on the screen. The least distance from the common central maximum to the point where the bright fringes due to both the wavelengths coincide is

(a) 1.56 mm (b) 7.2 mm
(c) 9.75 mm (d) 15.6 mm

19. An observer is moving with half the speed of light towards a stationary microwave source emitting waves at frequency 20 GHz. What is the frequency of the microwave measured by the observer ? (speed of light = 3×10^8 m s^{-1})

(a) 17.3 GHz (b) 12.1 GHz
(c) 34.6 GHz (d) 15.3 GHz

20. Four identical mirrors are made to stand vertically to form a square arrangement as shown in a top view. A ray starts from the midpoint M of mirror AD and after two reflections reaches corner D. Then, angle θ must be



(a) $\tan^{-1}(0.75)$ (b) $\cot^{-1}(0.75)$
(c) $\sin^{-1}(0.75)$ (d) $\cos^{-1}(0.75)$

SOLUTIONS

1. **(a):** Here, $E_0 = 45$ V m^{-1}, $\upsilon = 1.5 \times 10^{10}$ Hz, $c = 3 \times 10^8$ m s^{-1}

Amplitude of the oscillating magnetic field,

$$B_0 = \frac{E_0}{c} = \frac{45 \text{ V m}^{-1}}{3\times10^8 \text{ m s}^{-1}} = 1.5\times10^{-7}\text{ T}$$

Total average energy density,

$$u_{av} = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}(8.85\times10^{-12})(45)^2 \text{ J m}^{-3}$$

$= 8.9 \times 10^{-9}$ J m^{-3}

2. **(b) :** As per lens maker's formula,

$$\frac{1}{f}=(\mu_l-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \qquad \text{...(i)}$$

For given convex lens, $\mu_l = 1.2$ and $f > 0$.
When it is dipped in water,

$$\frac{1}{f'}=\left(\frac{\mu_l}{\mu_w}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right) \qquad \text{...(ii)}$$

From eqns. (i) and (ii),

$$\frac{f'}{f}=\frac{(\mu_l-1)}{\left(\frac{\mu_l}{\mu_w}-1\right)}=\frac{(1.25-1)}{\left(\frac{1.25}{1.33}-1\right)} \qquad (\because\ \mu_w=1.33)$$

or $\quad f' = -\,4.16f;\ \because f > 0,$

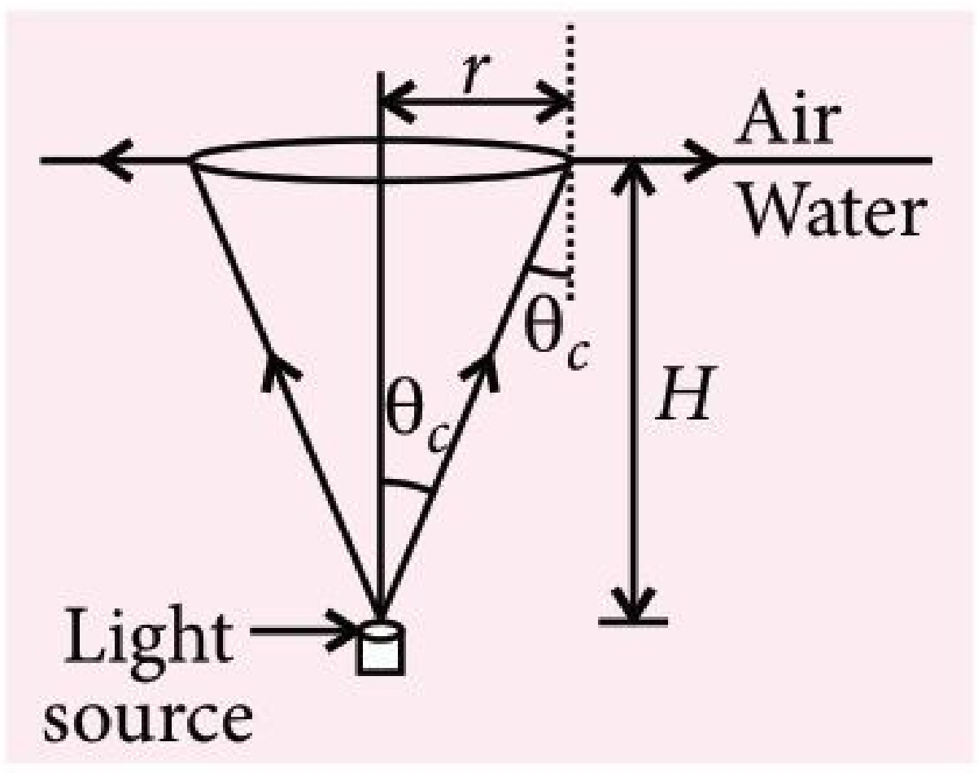
$\therefore \quad f' < 0$, *i.e.*, it will behave like a divergent lens.

3. **(d) :** For n^{th} secondary maximum, path difference

$a\sin\theta = (2n+1)\dfrac{\lambda}{2}$; For $n = 1$, $a\sin\theta = \dfrac{3\lambda}{2}$

4. **(a)**

5. **(a):** The figure shows incidence of ray from water at critical angle θ_c,



Now, $\sin\theta_c = \dfrac{1}{\mu}$

So that $\tan\theta_c = \dfrac{1}{(\mu^2-1)^{1/2}}$

From figure, $\tan\theta_c = \dfrac{r}{H}$

where r is the radius of the disc.

$\therefore$ Diameter of the disc $= 2r = 2h\tan\theta_c = \dfrac{2H}{(\mu^2-1)^{1/2}}$

6. **(c)**

7. **(b) :** Power of the lens combination is

$$P = P_1 + P_2 = \frac{1}{f_1(\text{in m})}+\frac{1}{f_2(\text{in m})}$$

$$=\frac{1}{+0.50\,\text{m}}+\frac{1}{-0.25\,\text{m}} = -\,2\ \text{m}^{-1} = -2\ \text{D}$$

8. **(a):** The angular wave number, $k = \dfrac{2\pi}{\lambda}$, where λ is the wavelength. The angular frequency is $\omega = 2\pi\upsilon$

$$\text{Ratio, } \frac{k}{\omega}=\frac{2\pi/\lambda}{2\pi\upsilon}=\frac{1}{\upsilon\lambda}=\frac{1}{c} = \text{constant}$$

9. **(b) :** $I = 4I_0\cos^2\dfrac{\phi}{2} \Rightarrow 2I_0 = 4I_0\cos^2\dfrac{\phi}{2}$

$$\therefore \quad \cos\frac{\phi}{2}=\frac{1}{\sqrt{2}} \ \Rightarrow\ \phi = 2\times\frac{\pi}{4}=\frac{\pi}{2}$$

$$\text{Path difference, } \Delta x = \frac{\lambda}{2\pi}\times\phi = \frac{\lambda}{2\pi}\frac{\pi}{2}=\frac{\lambda}{4}$$

$$\Rightarrow \quad (\mu-1)t = \frac{\lambda}{4} \text{ or } \left(\frac{6}{5}-1\right)t=\frac{\lambda}{4}\ ;\ \frac{t}{5}=\frac{\lambda}{4}, t=\frac{5\lambda}{4}$$

10. **(a)**

11. **(d) :** As we know,

$$\oint \overrightarrow{B}\cdot\overrightarrow{dl} = \mu_0(I_D + I_C) = \mu_0\left(\varepsilon_0\frac{d\phi}{dt}+0\right)$$

$$\Rightarrow B\cdot 2\pi R = \mu_0\varepsilon_0\left(\frac{dE}{dt}\right)\left(\pi\frac{d^2}{4}\right)$$

$$\therefore \ B = \frac{\mu_0\varepsilon_0}{2\pi R}\left(\frac{\pi d^2}{4}\right)\frac{dE}{dt}$$

$$=\frac{2\times10^{-7}\times8.85\times10^{-12}\times3.14\times0.01\times40}{4\times0.12}$$

$$= 4.63\times10^{-18}\ \text{T}$$

12. **(d) :** Given : $\vec{B} = B_0\sin(kx+\omega t)\hat{j}$ T

The relation between electric and magnetic field is,

$c = \dfrac{E}{B}$ or $E = cB$

The electric field component is perpendicular to the direction of propagation and the direction of magnetic field. Therefore, the electric field component along z-axis is obtained as

$$\vec{E} = cB_0\sin(kx+\omega t)\hat{k}\ \text{V/m}$$

13. **(b) :** The resolving power of an optical microscope,

$$RP = \frac{2\mu\sin\theta}{\lambda};\ \therefore \frac{\text{RP}_1}{\text{RP}_2}=\frac{7000}{4000}=\frac{7}{4}$$

14. **(c):** Position of 9^{th} bright fringe in medium,

$$x = \frac{9\lambda_m D}{d}$$

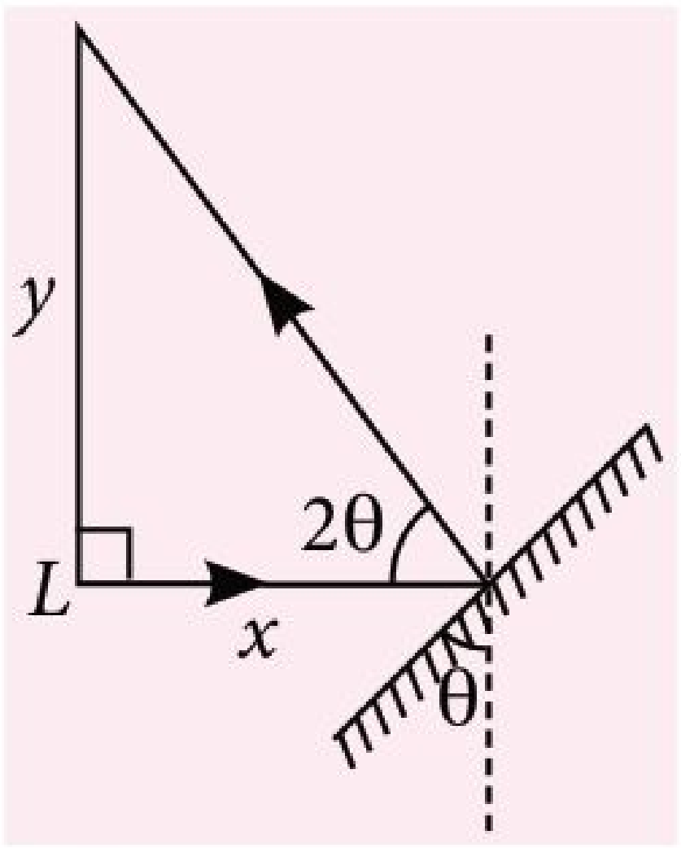
Position of 5^{th} dark fringe in air,

$$x' = \frac{(5-1/2)\lambda_{\text{air}}D}{d}=\frac{4.5\lambda_{\text{air}}D}{d}$$

Given $x = x'$

$$\therefore \quad \frac{9\lambda_m D}{d}=\frac{4.5\lambda_{\text{air}}D}{d};\ \mu_m = \frac{\lambda_{\text{air}}}{\lambda_m}=\frac{9}{4.5}\approx 2$$

15. **(d) :** When mirror is rotated by θ, reflected ray will be rotated by 2θ.



For small angle θ,

$\tan 2\theta \approx 2\theta = \dfrac{y}{x} \quad \therefore\ \theta = \dfrac{y}{2x}$

16. **(a):** The condition for dispersion without deviation is given as $(\mu - 1)A = (\mu' - 1)A'$

Given $\mu = 1.42$, $A = 10°$, $\mu' = 1.7$, $A' = ?$

$\therefore$ $(1.42 - 1) \times 10 = (1.7 - 1)A'$; $(0.42) \times 10 = 0.7 \times A'$

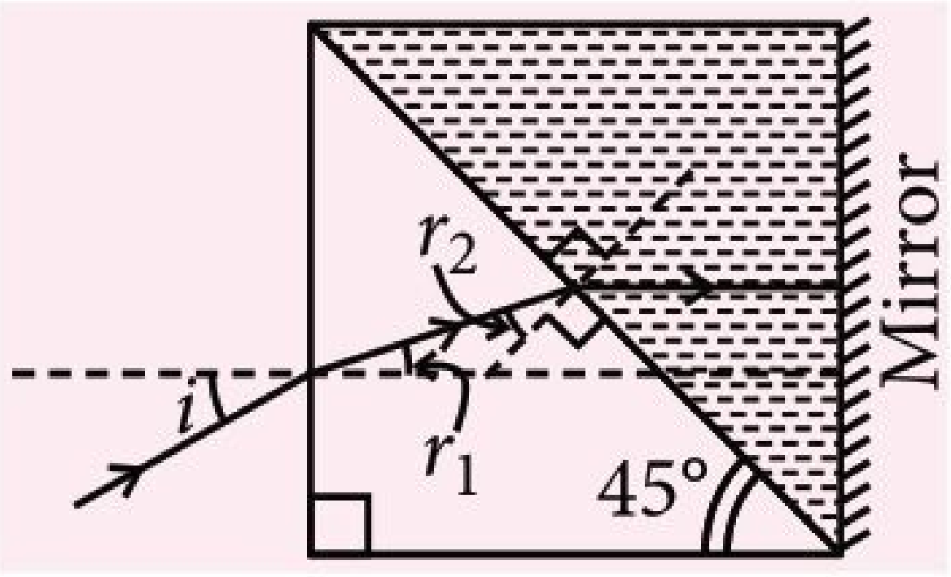
or $A' = \dfrac{0.42 \times 10}{0.7} = 6°$

17. **(b) :** Since incident ray retraces its path, it must strike the plane mirror perpendicularly.

From Snell's law, $\quad \sin i = \mu_1 \sin r_1 \qquad$ ...(i)

and $\mu_1 \sin r_2 = \mu_2 \sin 45° \Rightarrow \mu_1 \sin r_2 = \dfrac{\mu_2}{\sqrt{2}} \qquad$ ...(ii)

$$\Rightarrow \quad r_2 = \sin^{-1}\left(\frac{\mu_2}{\sqrt{2}\mu_1}\right)$$



Also, $r_1 + r_2 = \dfrac{\pi}{4}$

$$\therefore \quad r_1 = \frac{\pi}{4} - \sin^{-1}\left(\frac{\mu_2}{\sqrt{2}\mu_1}\right) \qquad \text{(Using (ii))}$$

From eqn. (i),

$$\therefore \quad i = \sin^{-1}\left[\mu_1 \sin\left(\frac{\pi}{4} - \sin^{-1}\frac{\mu_2}{\sqrt{2}\mu_1}\right)\right]$$

18. **(b) :** Let y be the distance from the central maximum to the point where the bright fringes due to both the wavelengths coincides.

Now, for λ_1, $y = \dfrac{m\lambda_1 D}{d}$; for λ_2, $y = \dfrac{n\lambda_2 D}{d}$

$$\therefore \quad m\lambda_1 = n\lambda_2 ; \ \frac{m}{n} = \frac{\lambda_2}{\lambda_1} = \frac{480}{600} = \frac{4}{5}$$

i.e., with respect to central maximum, 4th bright fringe of λ_1 coincides with 5th bright fringe of λ_2.

Now, $y = \dfrac{4 \times 600 \times 10^{-9} \times 1.5}{0.5 \times 10^{-3}}$ m $= 7.2$ mm

19. **(c) :** Frequency of the microwave measured by the observer will be given by Doppler's effect of light.

$$\frac{\upsilon'}{\upsilon} = \sqrt{\frac{1+\beta}{1-\beta}} \qquad \left(\text{Here } \beta = \frac{v}{c}\right)$$

$$\Rightarrow \quad \frac{\upsilon'}{\upsilon} = \sqrt{\frac{1+v/c}{1-v/c}} = \sqrt{\frac{c+v}{c-v}} = \sqrt{\frac{c+c/2}{c-c/2}} = \sqrt{3}$$

$$= 20\sqrt{3}\ \text{GHz} = 34.6\ \text{GHz}$$

20. **(b)**

◆

PMs' Museum: a peek into India's space journey, ancient knowledge

"IT was the 5th century when Aryabhatta told us that the Earth revolves around its axis," the voice-over said, as an image of the Indian mathematician beamed from the light-and-sound show.

"In the 12th century, another legendary Indian mathematician, Bhaskaracharya recognised the force of gravity, which finds mention in astronomer Varahamiri's work Surya Siddhant," the narration went on to say, the baritone lent by actor Amitabh Bachchan.

"It was only 500 years later, in the 17th century, that the Western world announced the law of gravity," Bacchan added, referring to Newton's discovery in 1687.

The programme on ancient Indian knowledge was part of a light and sound show at the Prime Minister's Museum in Teen Murti. Launched earlier this week, the show is dedicated to India's space programme.

While pitching India as the birthplace of 'zero' and 'decimal' and detailing its accomplishments in mathematics and astronomy, the event showcased the contribution of the country's prime ministers towards India's space journey.

Formatted as a conversation between 'Bharat' and an inquisitive young girl seeking to know about the universe, the 30-minute episode spoke about Jawaharlal Nehru, during whose tenure Vikram Sarabai established India's space research organisation INCOSPAR (now called ISRO) while also building the rocket launchpad in Thumba, a village in Kerala.

It highlighted how Lal Bahadur Shastri used space to beam Krishi Darshan, benefitting farmers with useful information, and also his launch of the satellite Aryabhata.

The programme talked of India's landmark moment in 1984 when, during Indira Gandhi's tenure, the first Indian, Wing Commander Rakesh Sharma, went to space. With Sharma himself present at the launch of the show, besides Union Ministers Meenakshi Lekhi and Arjun Meghwal, his conversation from space with Gandhi was also played. Nehru Memorial Museum & Library (NMML) Curator Vintee Sain said the premiere "chronicles India's growth in space technology in the post-Independence decade."

"With humble beginnings when the rocket parts and payloads were ferried over cycles and bullock carts for launch, India has come a long way and is now part of an exclusive club of countries with a thriving space programme," she said.

The episode also mentioned Atal Bihari Vajpayee's 2003 declaration from the ramparts of the Red Fort that India is ready to send its vehicle to the moon, which was realised during Manmohan Singh's tenure in 2008 with Chandrayan 1.

The show's final segment is devoted to Prime Minister Narendra Modi, playing clippings of his speeches extolling India's space programme, India reaching Mars and the country launching a record 104 satellites in 2017.

It also puts Modi at the centrestage of the space programmes in the future.

The production has been supervised by Prasoon Joshi, Chairman of Central Board of Film Certification, while the show has been prepared under the guidance of the NMML Executive Council members.

'The show highlights how our achievements in space have ushered in a phase of space diplomacy for India, as we have been launching satellites of foreign countries and aim to achieve the first Human space flight programme (Gaganyaan) and interplanetary Missions to Venus (Shukrayaan) and Solar exploratory Mission (Aditya)," Sain said.

The second show at the museum-to be launched in February - will cover the story of unsung women warriors in India's struggle for Independence.

Pradhanmantri Sangrahalaya is also readying a gallery on PM Modi, as per officials, which is scheduled to open for the public around the same time.

Courtesy : The Indian Express

WORD GRID

Readers are
requested to send
their responses of
word grid.
Be the Winner!

Find and encircle the words in the given grid, running in one of the possible directions; horizontal, vertical or diagonal by reading the clues given below.

R	E	B	D	E	F	G	F	I	O	P	L	F	D	D	B	M	V
A	Q	P	Z	N	D	E	L	D	W	D	H	L	P	I	R	E	L
C	A	O	R	S	I	O	B	I	L	I	Y	E	D	S	S	L	T
O	E	L	A	S	T	O	M	E	R	S	R	O	W	P	I	O	B
N	I	I	O	B	E	N	B	T	O	R	S	W	R	L	L	V	D
D	S	I	O	W	J	O	U	L	E	X	Y	L	Q	A	C	I	I
U	T	L	G	A	L	Y	Q	B	S	E	P	D	B	C	L	O	F
C	A	R	L	H	V	O	W	X	C	Q	M	O	P	E	O	L	F
T	N	X	I	V	S	Z	U	M	A	C	H	N	U	M	B	E	R
I	B	A	S	O	E	E	M	U	P	C	L	Y	M	E	K	T	A
V	U	Q	T	G	L	R	F	M	E	B	Q	K	G	N	G	A	C
I	L	D	C	L	P	V	C	G	V	S	U	S	Q	T	P	U	T
T	P	X	S	I	D	A	G	N	E	S	Y	D	R	O	J	C	I
Y	T	N	E	S	E	M	E	T	L	E	p	O	C	E	N	L	O
K	R	B	L	T	P	M	U	I	O	L	A	O	K	K	W	O	N
O	I	N	K	L	G	T	A	E	C	Y	C	L	O	T	R	O	N
U	N	Z	I	N	G	O	R	S	I	T	I	P	S	Y	T	S	Z
G	O	P	W	Q	U	A	L	I	T	Y	F	A	C	T	O	R	N
A	E	N	E	R	D	I	Y	F	Y	S	T	E	E	R	N	G	E

Across

1. S.I unit of heat energy.
2. Substances which can be stretched to cause large strain.
3. The ratio of speed of a body to the speed of sound.
4. A machine which is used to accelerate the charged particles.
5. Sharpness of resonance of LCR circuit.

Down

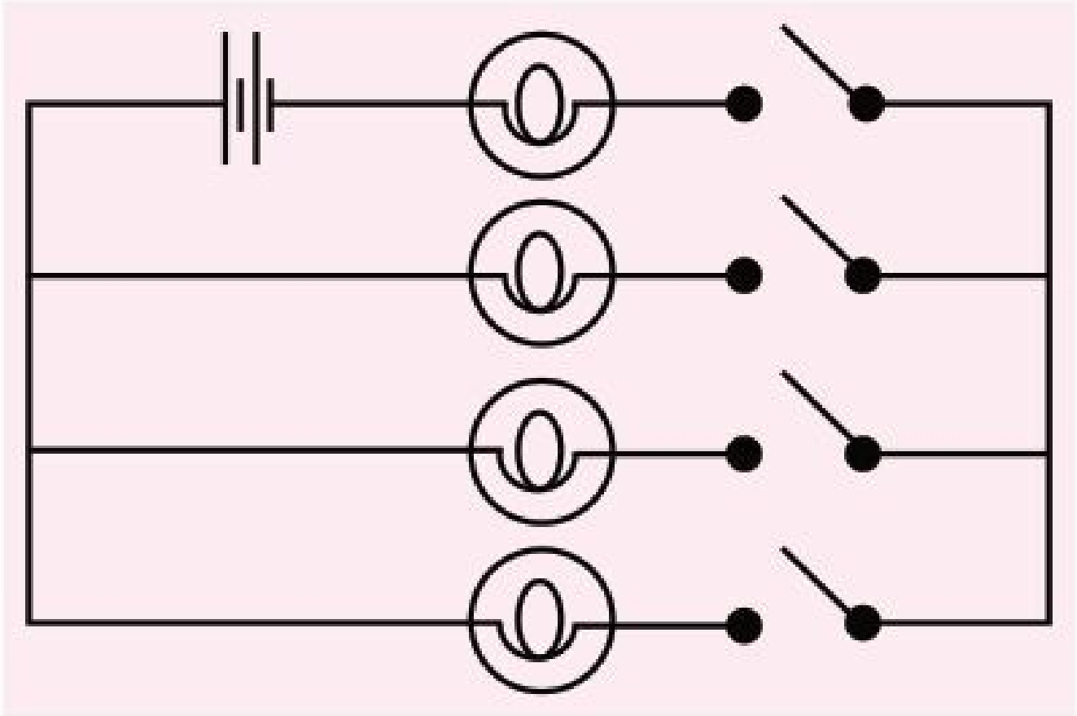
1. Area under velocity-time graph.
2. Reciprocal of resistivity.
3. The colour of light having minimum wavelength.
4. The phenomenon due to which we see colours when CD is viewed.
5. The minimum speed required for an object to escape from earth's surface.

*Please send entries of solutions both with words and scanned copy of the grid by 10th of every month.

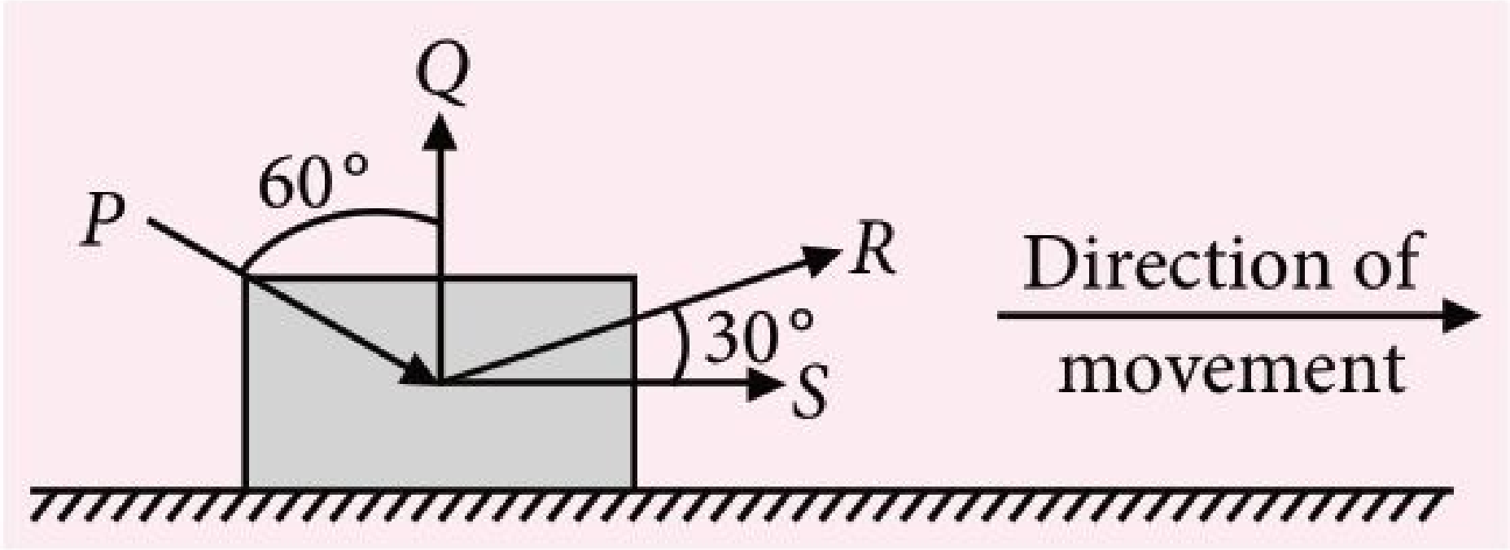
Quiz CLUB

Unlock Your Knowledge!

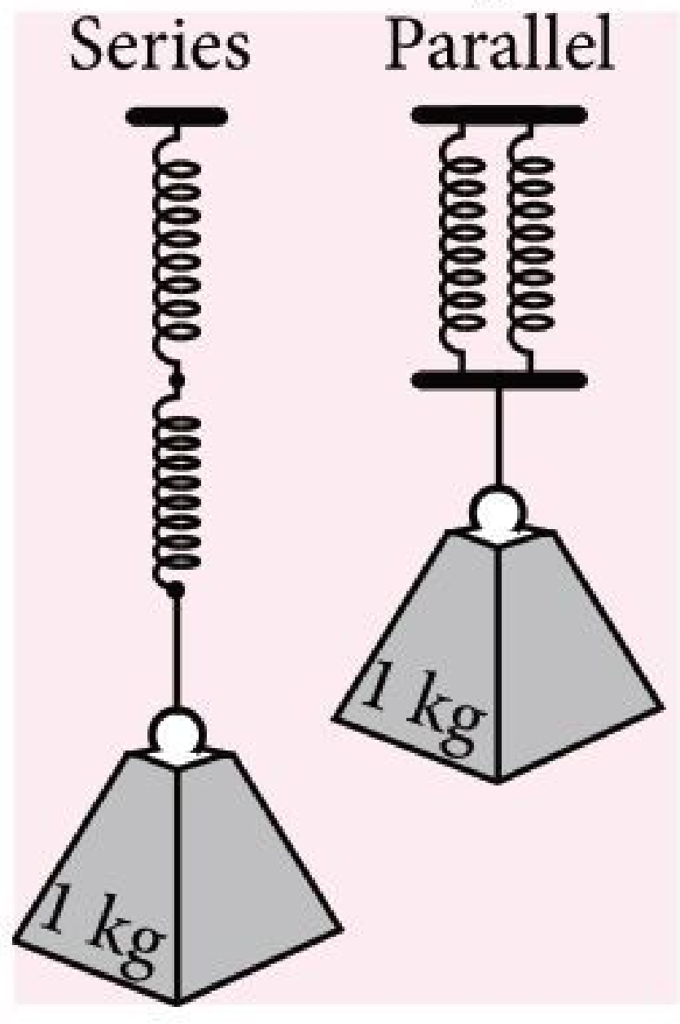
1. Name the mirror which always forms an erect image of the object.
2. Name the phenomenon on which the absorption of ink by the blotting paper depends.
3. Name the unit in which the nuclear sizes are expressed.
4. Light bulb filament violates Ohm's law. State True or False.
5. Which layer of the Earth's atmosphere is useful in long distance radio transmission?
6. Why we add some suitable impurities to a pure semiconductor?
7. Which natural phenomena, is known as 'deer's thirst' in Sanskrit ?
8. How many switches need to be closed to light up one bulb?



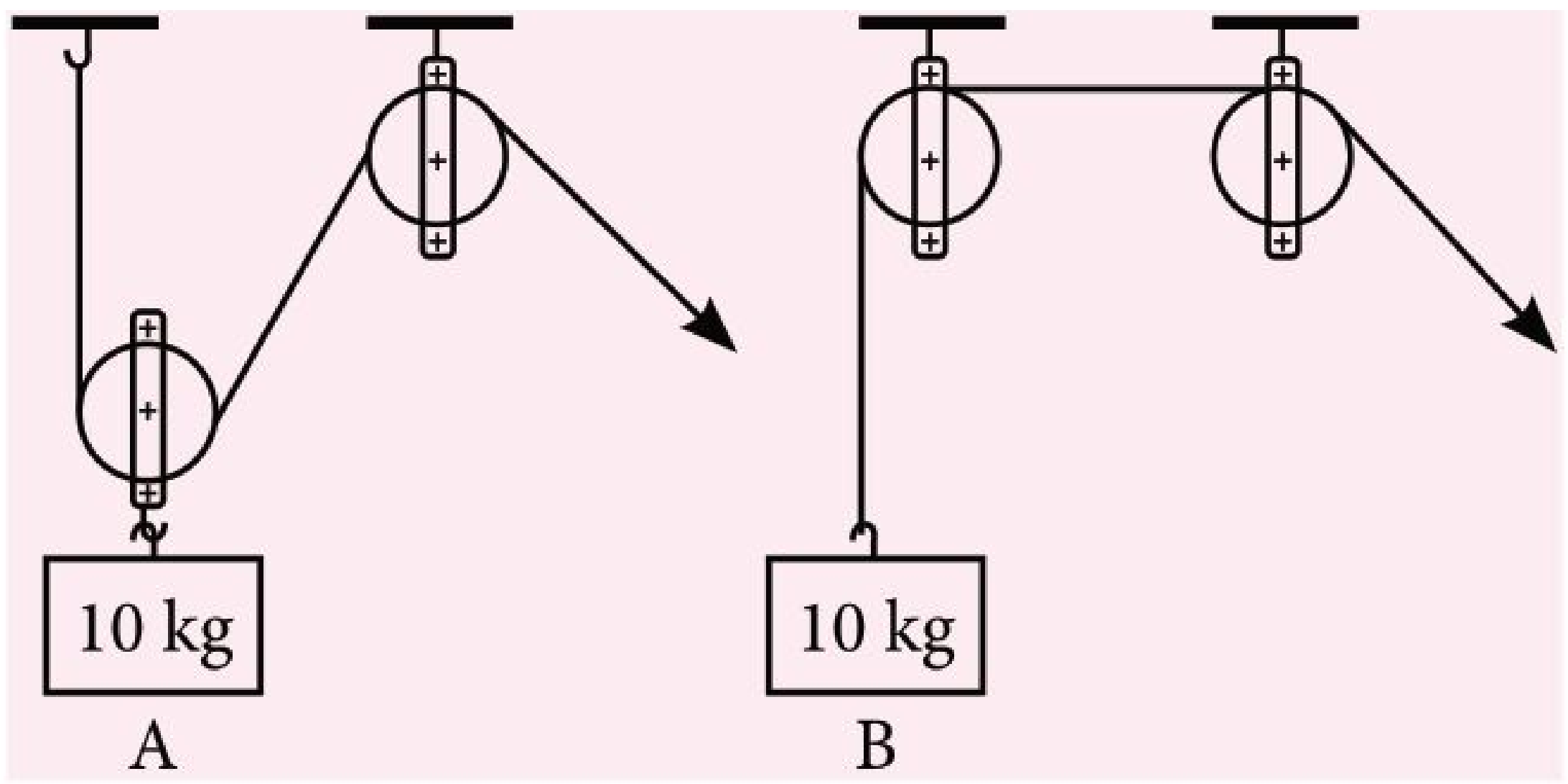
9. Name the physical quantity which can be measured in light year.
10. For which phenomena, Sir C.V. Raman was awarded Nobel Prize for his work?
11. Name the technique used to estimate the age of rocks.
12. Name the phenomenon on which the optical fibre works.
13. Name the device used to maintain normal atmospheric pressure inside an aeroplane flying at high alttitude?
14. Four forces of equal magnitude are acting on an object as shown in figure. Which of the given forces does the least work?



15. If a force 1 kg elongated the springs in series by 10 cm, then what will be the total distance when the springs in parallel are elongated?



16. Name the colour which deviates the most when passing through a prism.
17. Which weight among *A* and *B* requires the least force to move?



18. If the distance between Sun and Earth becomes double the present distance, then what is the effect on gravitational force between Sun and Earth?
19. Name the substance used to slow down the speed of neutron in a nuclear reactor.
20. What is the value of coefficient of restitution for perfectly elastic collision?

◆ ◆

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

CBSE warm-up!

CLASS-XII

Practice questions for CBSE Exams as per the latest pattern
and reduced syllabus by CBSE for the academic session 2022-23.

Practice Paper 2022-23

Time Allowed : 3 hours
Maximum Marks : 70

General Instructions :

(i) There are 35 questions in all. All questions are compulsory.

(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.

(iii) Section A contains eighteen MCQ of 1 mark each, Section B contains seven questions of two marks each, Section C contains five questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.

(iv) There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.

(v) Use of calculators is not allowed.

SECTION - A

1. An electric dipole placed in a non-uniform electric field can experience
(a) a force but not a torque
(b) a torque but not a force
(c) always a force and a torque
(d) neither a force nor a torque

2. What is the geometrical shape of equipotential surfaces due to a single isolated charge?
(a) circular (b) cubical
(c) spherical (d) cylindrical

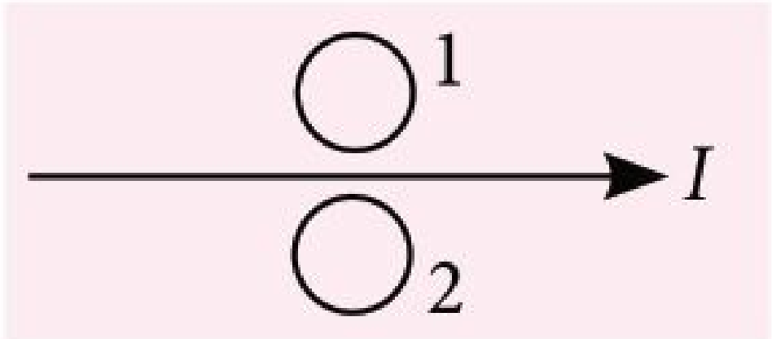
3. The ratio of current density and electric field is called
(a) resistivity (b) conductivity
(c) drift velocity (d) mobility

4. A forward biased p-n junction diode has a resistance of the order of
(a) 1 Ω (b) 1 kΩ
(c) 1 MΩ (d) none of these

5. An electron is released from rest in a region of uniform electric and magnetic fields acting parallel to each other. The electron will
(a) move in a straight line.
(b) move in a circle.
(c) remain stationary.
(d) move in a helical path.

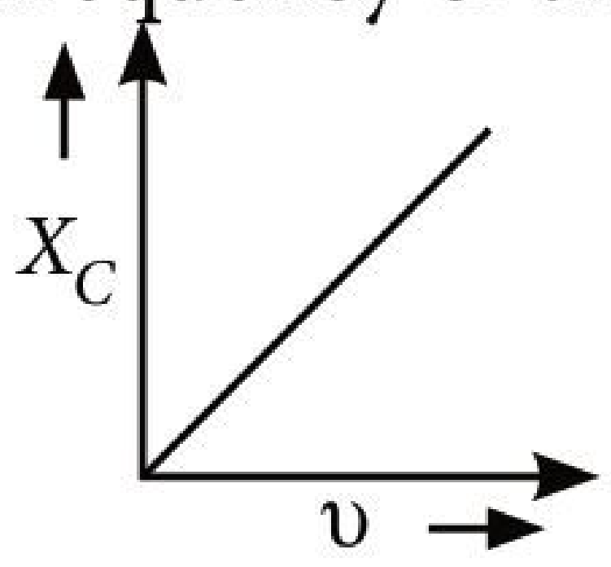
6. The magnetic dipole moment of a current carrying coil does not depend upon
(a) number of turns of the coil
(b) cross-sectional area of the coil
(c) current flowing in the coil
(d) material of the turns of the coil.

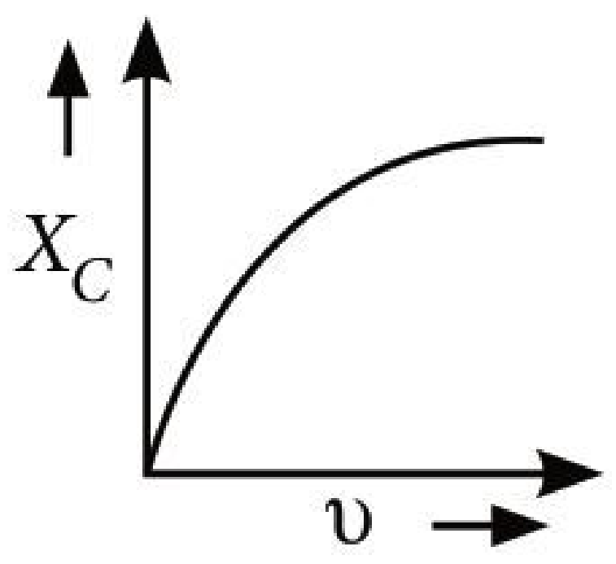
7. What is the direction of induced currents in metal rings 1 and 2 respectively when current I in the wire is increasing steadily ?

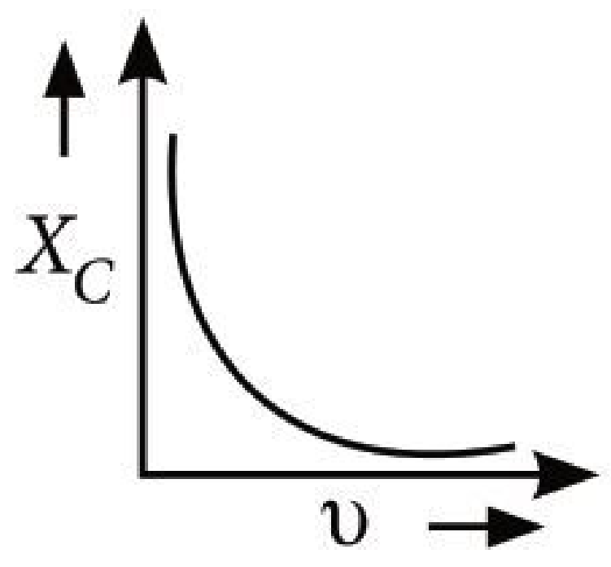


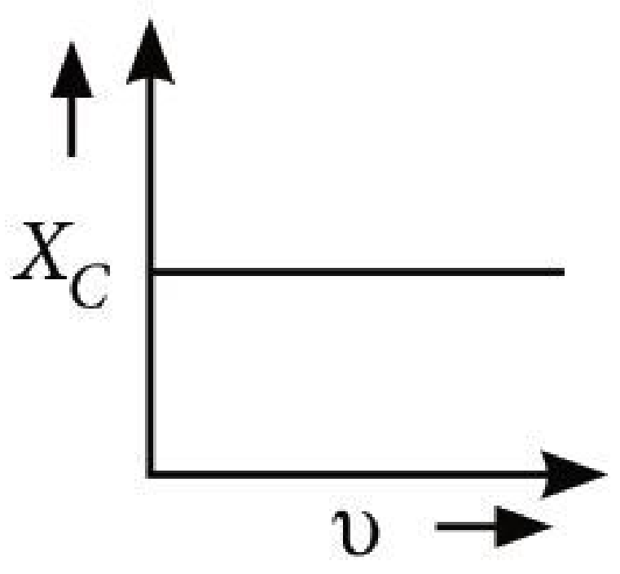
(a) Anticlockwise, clockwise
(b) Clockwise, clockwise
(c) Clockwise, anticlockwise
(d) Anticlockwise, anticlockwise

8. Which of the following graphs depticts the correct variation of capacitive reactance with the change in the frequency of the ac source?

(a) 

(b) 

(c) 

(d) 

9. Electromagnetic waves used as a diagnostic tool in medicine are
(a) X-rays (b) ultraviolet rays
(c) infrared radiation (d) ultrasonic waves.

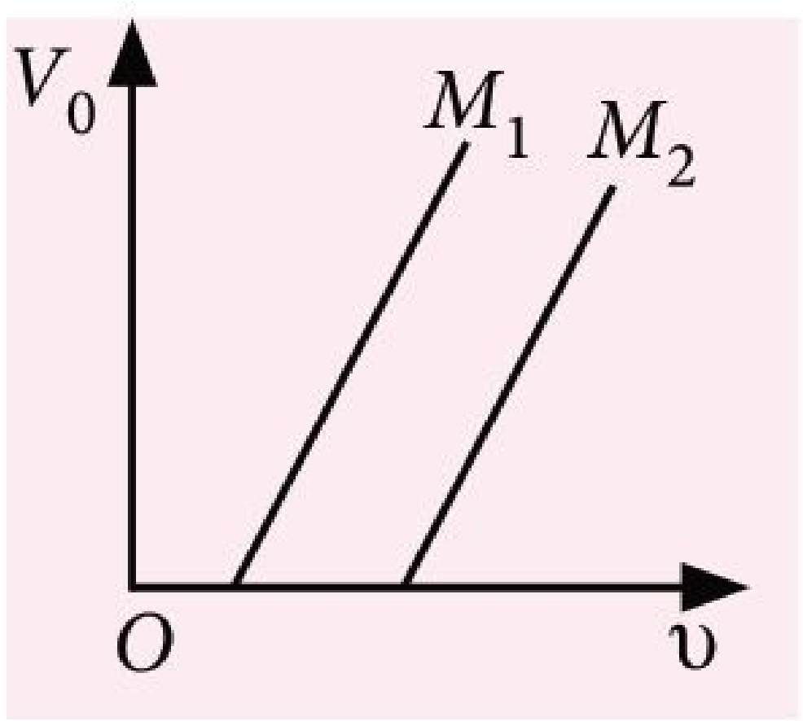
10. For the same value of angle of incidence, the angles of refraction in three media A, B and C are 15°, 25° and 35° respectively. In which media would the velocity of light be minimum?
(a) A (b) B
(c) C (d) data insufficient

11. A biconcave lens of power P vertically splits into two identical plano concave parts. The power of each part will be
(a) $2P$ (b) $P/2$ (c) P (d) $P/\sqrt{2}$

12. Binding energy of a system of masses (nucleon) is
(a) energy released when the system is forced
(b) energy that must be supplied to the system to separate its components.
(c) energy equivalence of mass defect
(d) All of these

13. The resolving power of a telescope can be increased by increasing
(a) wavelength of light
(b) diameter of objective
(c) length of the tube
(d) focal length of eyepiece.

14. The variation of the stopping potential (V_0) with the frequency (υ) of the light incident on two different photosensitive surfaces M_1 and M_2 is shown in the figure. If ϕ, and ϕ_2 be the work function for surfaces M_1 and M_2 respectively, then



(a) $\phi_1 = \phi_2$ (b) $\phi_1 > \phi_2$
(c) $\phi_2 > \phi_1$ (d) None of these

15. In fission, the percentage of mass converted into energy is about
(a) 0.01 % (b) 0.1 % (c) 1 % (d) 10 %

For question numbers 16-18, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true but R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false and R is also false.

16. **Assertion :** When current through a bulb decreases by 0.5%, the glow of bulb decreases by 1%.
Reason : Glow (Power) which is directly proportional to square of current.

17. **Assertion** : In interference, all the fringes are of same width.
Reason : In interference, fringe width is independent of position of the fringe.

18. **Assertion** : Silicon is preferred over germanium for making semiconductor devices.
Reason : The energy band for germanium is more than the energy band of silicon.

SECTION - B

19. An α-particle and a proton are accelerated through the same potential difference. Find the ratio of their de Broglie wavelengths.

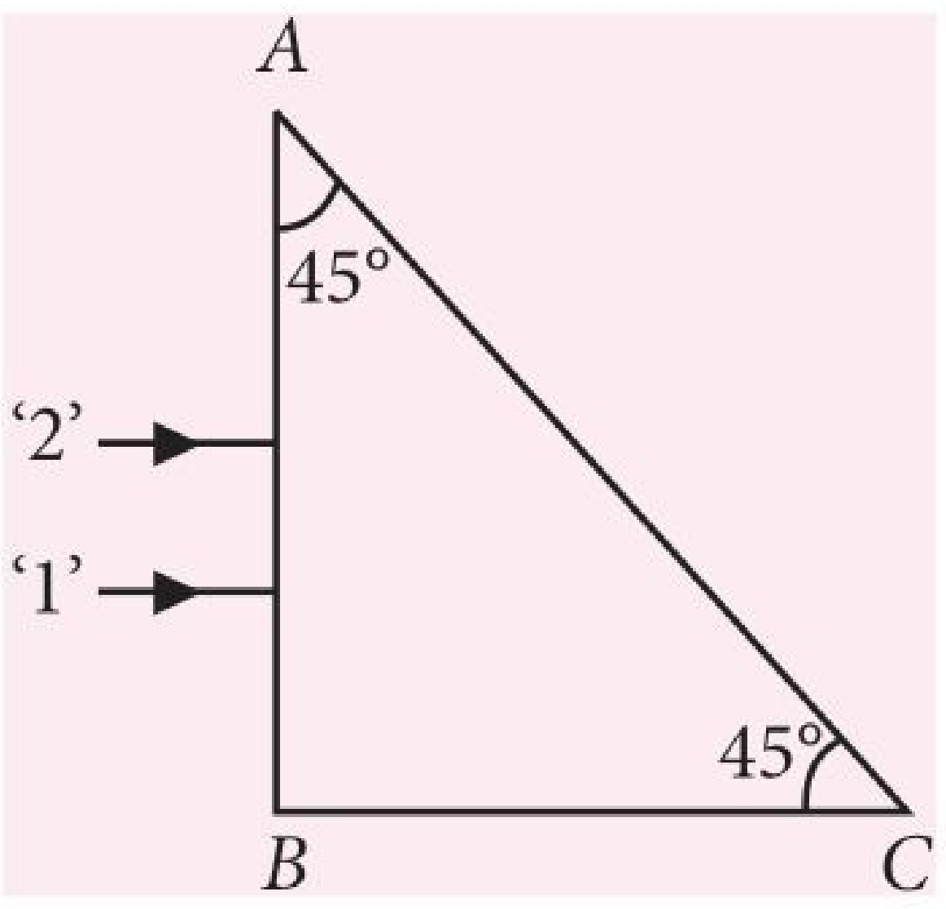
20. (a) Write the conditions under which light sources can be said to be coherent.
(b) Why is it necessary to have coherent sources in order to produce an interference pattern?

21. Current in a circuit falls steadily from 5.0 A to 0.0 A in 100 ms. If an average e.m.f. of 200 V is induced, calculate the self-inductance of the circuit.

OR

Starting from the expression for the energy $W = \frac{1}{2}LI^2$, stored in a solenoid of self-inductance L to build up the current I, obtain the expression for the magnetic energy in terms of the magnetic field B, area A and length l of the solenoid having n number of turns per unit length. Hence, show that the energy density is given by $B^2/2\mu_0$.

22. Two monochromatic rays of light are incident normally on the face AB of an isosceles right-angled prism ABC. The refractive indices of the glass prism for the two rays '1' and '2' are respectively 1.33 and 1.45. Trace the path of these rays after entering the prism.



23. Calculate (a) the wavelength and (b) the frequency of the H_β line of the Balmer series for hydrogen.

OR

What is the role of control rods in a nuclear reactor? Why are they made of cadmium?

24. **(i)** Name the three elements of the Earth's magnetic field.

(ii) Where on the surface of the Earth is the vertical component of the Earth's magnetic field zero?

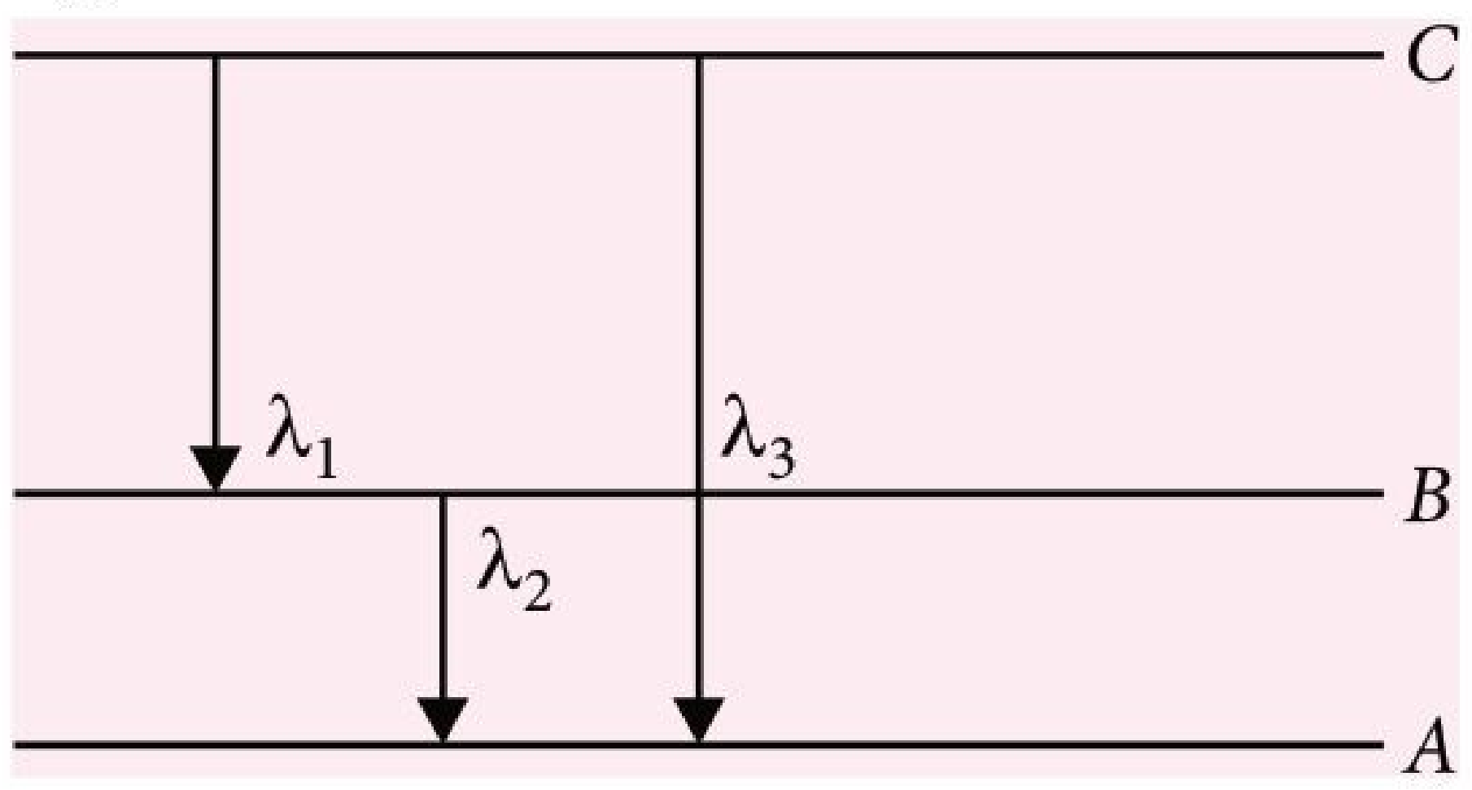
25. Why are alkali metal surfaces most suited as photosensitive surfaces?

SECTION - C

26. Increase in current sensitivity results in an increase in voltage sensitivity of a moving coil galvanometer. Yes or no? Justify your answer.

27. **(i)** State Bohr's quantization condition for defining stationary orbits. How does de-Broglie hypothesis explain the stationary orbits ?

(ii) Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown in the figure.



28. **(a)** The resistance of iron and copper wires at 20°C are 3.9 Ω and 4.1 Ω respectively. At what temperature will the resistance be equal? Temperature coefficient of resistivity for iron is $5.0 \times 10^{-3}\ K^{-1}$ and for copper it is $4.0 \times 10^{-3}\ K^{-1}$. Neglect the thermal expansion.

(b) In case the two cells are identical, each of emf $E = 5$ V and internal resistance $r = 2\ \Omega$, calculate voltage across the external resistance $R = 10\ \Omega$.

OR

Draw the circuit diagram of a meter bridge to explain how it is based on Wheatstone bridge.

29. An electron of mass m_e revolves around a nucleus of charge $+Ze$. Show that it behaves like a tiny magnetic dipole. Hence prove that the magnetic moment associated with it is expressed as $\vec{\mu} = -\frac{e}{2m_e}\vec{L}$, where $\vec{L}$ is the orbital angular momentum of the electron. Give the significance of negative sign.

OR

Two identical coils, each of radius 'R' and number of turns 'N' are lying in perpendicular planes such that their centres coincide. Find the magnitude and direction of the resultant magnetic field at the centre of the coils, if they are carrying currents I and $\sqrt{3}I$ respectively.

30. With the help of a labelled diagram, explain the working of a step-up transformer. Give reasons to explain the following :

(i) The core of the transformer is laminated.

(ii) Thick copper wire is used in windings.

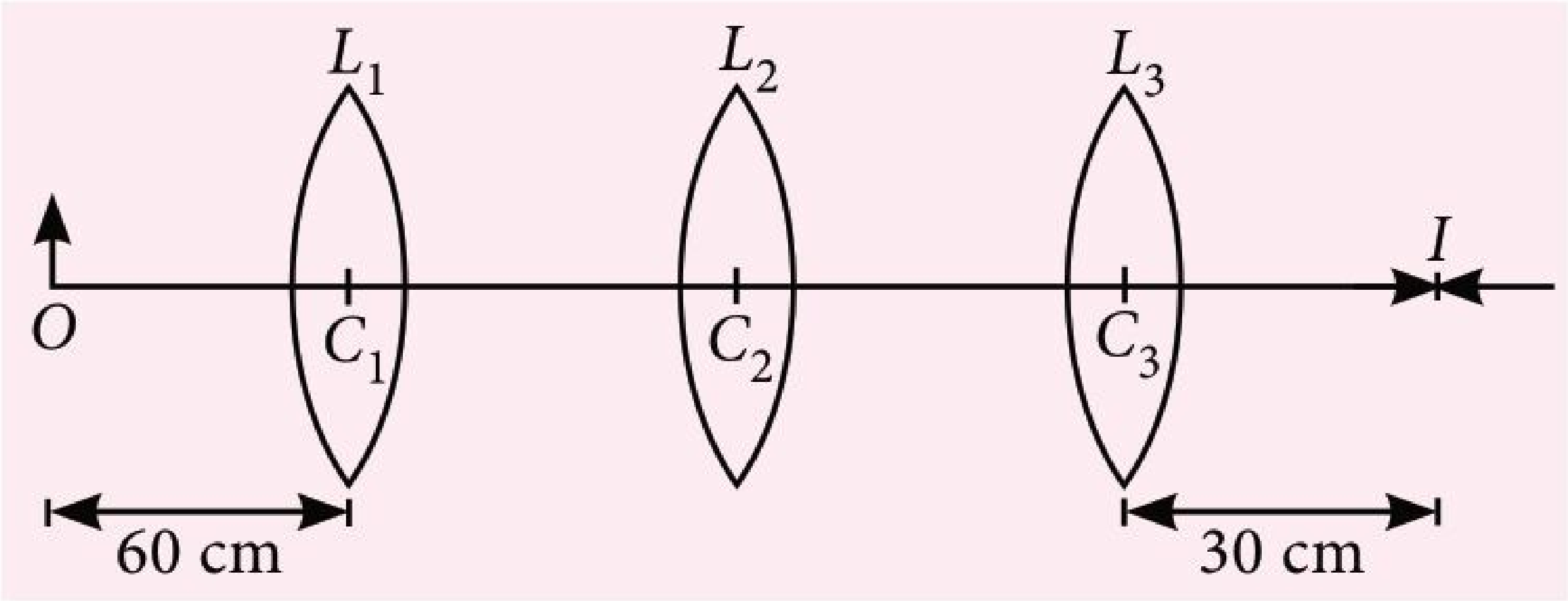
SECTION - D

31. Draw the energy band diagram of (i) n-type, and (ii) p-type semiconductors at temperatures $T > 0$ K. In the case of n-type semiconductor, the donor energy level is slightly below the bottom of conduction band whereas in p-type semiconductor, the acceptor energy level is slightly above the top of valence band. Explain, giving examples, what role do these energy levels play in conduction and valence bands.

OR

Explain with the help of a circuit diagram, the working of a p-n junction diode as a half wave rectifier.

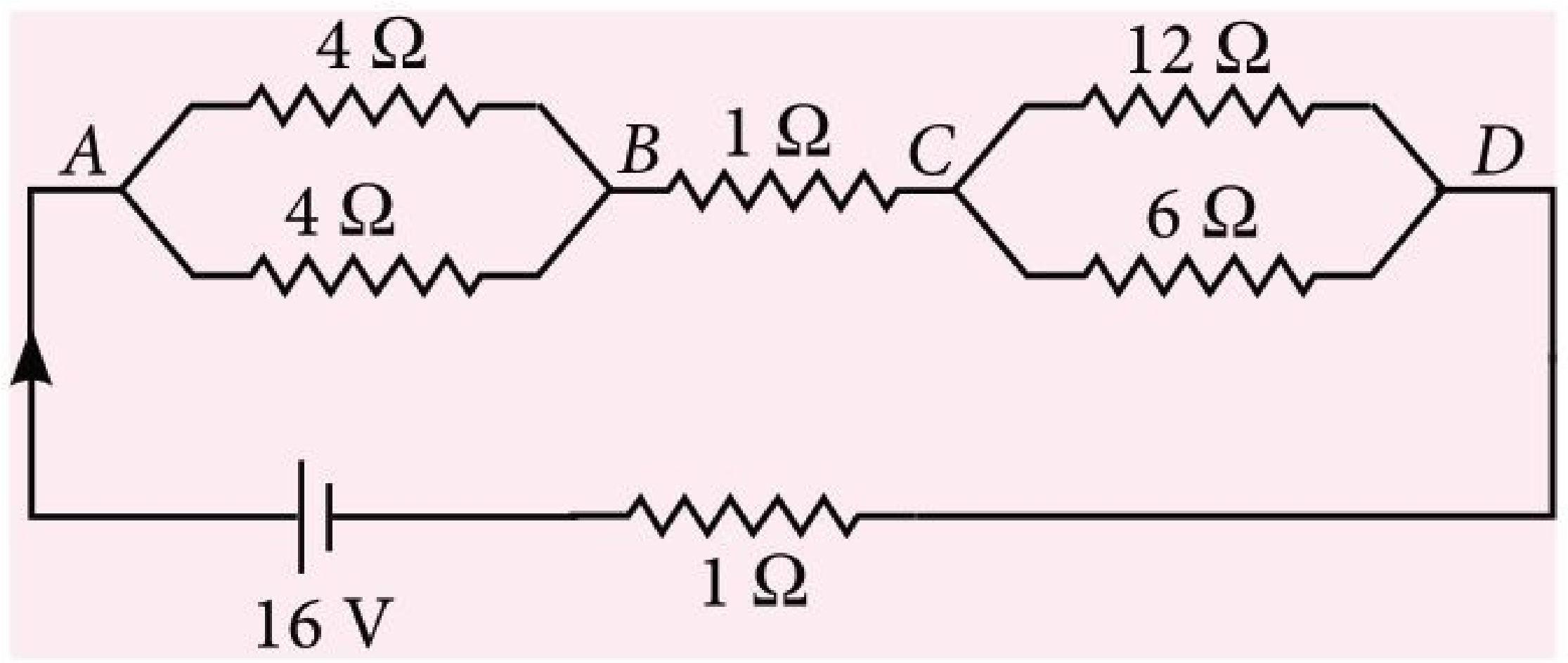
32. Three lenses L_1, L_2, L_3 each of focal length 30 cm are placed co-axially as shown in figure
An object is held at 60 cm from the optical of centre of lens L_1. The final real image is formed at the focus of L_3. Calculate separation between (i) L_1 and L_2 (ii) L_2 and L_3?



OR

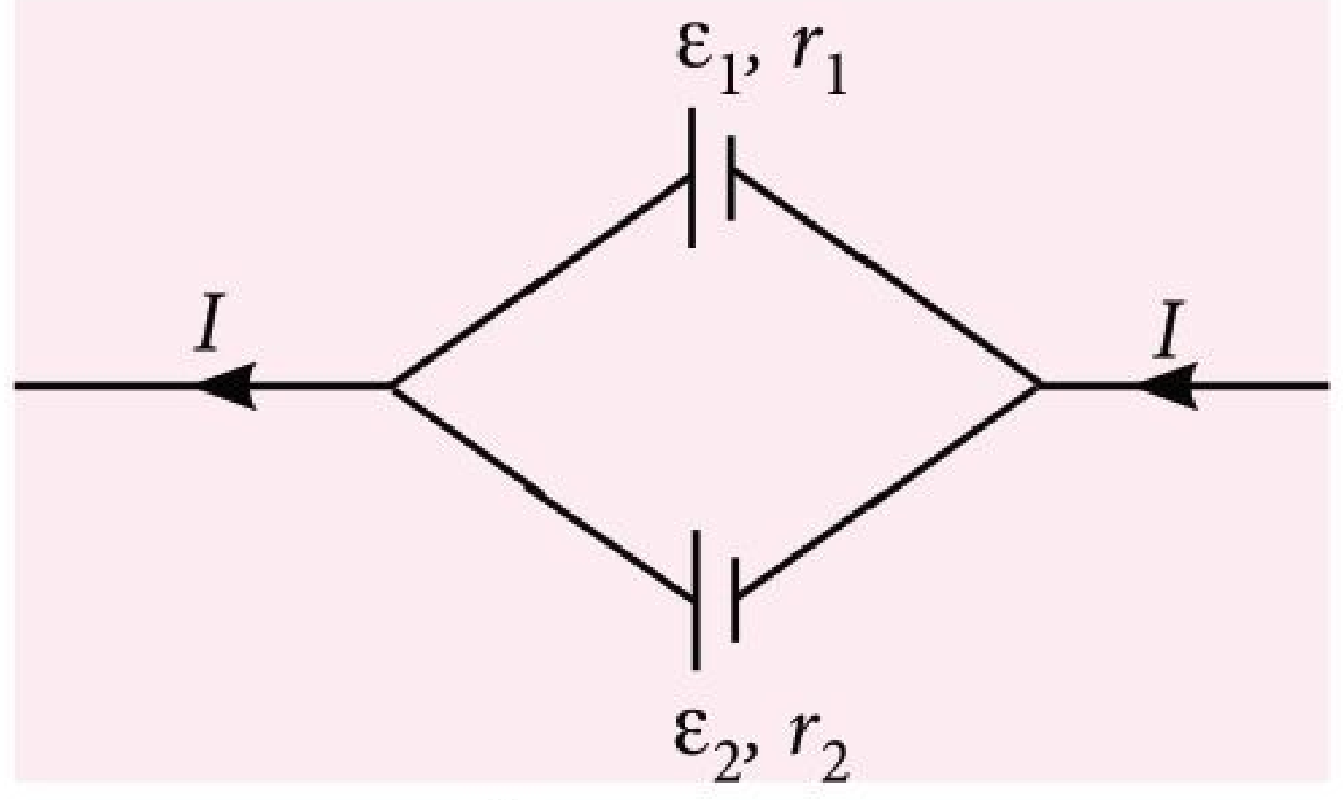
Using lens maker's formula, derive the thin lens formula $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ for a biconvex lens.

33. A network of resistors is connected to a 16 V battery of internal resistance of 1 Ω as shown in the figure. Obtain the voltage drops V_{AB} and V_{CD}.



OR

Two cells of emf ε_1, ε_2 and internal resistance r_1 and r_2 respectively are connected in parallel as shown in the figure.



Deduct the expression for

(i) The equivalent emf of the combination.

(ii) The equivalent resistance of the combination.

(iii) The potential difference between the points A and B.

SECTION - E

34. Read the following paragraph and answer the questions.

Case Study : Parallel plate capacitor

Parallel plate capacitor consists of two similar flat conducting plates, arranged parallel to one another, separated by a distance. Its capacitance is given by $C=\frac{K\varepsilon_0 A}{d}$, where A is area of each plate, d is separation between the two plates, and K is the dielectric constant.

When a dielectric slab of thickness t introduced between the plates, then the capacitance of a parallel plate capacitor is increased as redistribution of charges takes place due to dielectric.

When a metallic conductor of thickness t is introduced between the plates, then capacitance of a parallel plate capacitor is again increased.

(i) When two identical capacitors are charged individually to different potential and then connected in parallel, after disconnecting from the source, what will be the change in net energy stored in the two capacitors?

(ii) In a parallel plate capacitor of capacitance (C), if the intervening medium of permittivity ε between the plates is replaced by another medium of permittivity $\frac{\varepsilon}{2}$, then what will be the value of new capacitance?

(iii) A parallel plate capacitor has an electric field of 10^5 V/m between the plates. If the charge on the capacitor plate is 1 μC, then calculate the force (in N) on each capacitor plate.

PUBLIC NOTICE

NTA Examination Calendar for Academic Year 2023-24

The Ministry of Education (MoE), Government of India (GoI) has established the National Testing Agency (NTA) as an independent, autonomous, and self-sustained premier testing organization under the Societies Registration Act (1860) for conducting efficient, transparent, and international standardized tests in order to assess the competency of candidates for admission to premier higher education institutions with a mission to improve equity and quality in education by developing and administering research-based valid, reliable, efficient, transparent, fair and international level assessments.

For the **Academic year 2023-24,** following is the Calendar for some major examinations to be conducted by the NTA:

S.No.	Name of Examination	Dates of Examinations	Reserve Dates
1.	Joint Entrance Examination [JEE (Main)] – 2023 Session 1	24, 25, 27, 28, 29, 30, 31 January 2023	01, 02, 03 February 2023
2.	Joint Entrance Examination [JEE (Main)] – 2023 Session 2	06, 08, 10, 11, 12 April 2023	13, 15 April 2023
3.	ICAR AIEEA 2023	26, 27, 28, 29 April 2023	
4.	National Eligibility cum Entrance Test [NEET (UG)] – 2023	07 May 2023	
5.	Common University Entrance Test (CUET) 2023	21 to 31 May 2023	01 to 07 June 2023

For further clarification related to the examination dates and other instructions, the Candidates are advised to visit the official website of NTA **www.nta.ac.in** for the latest updates.

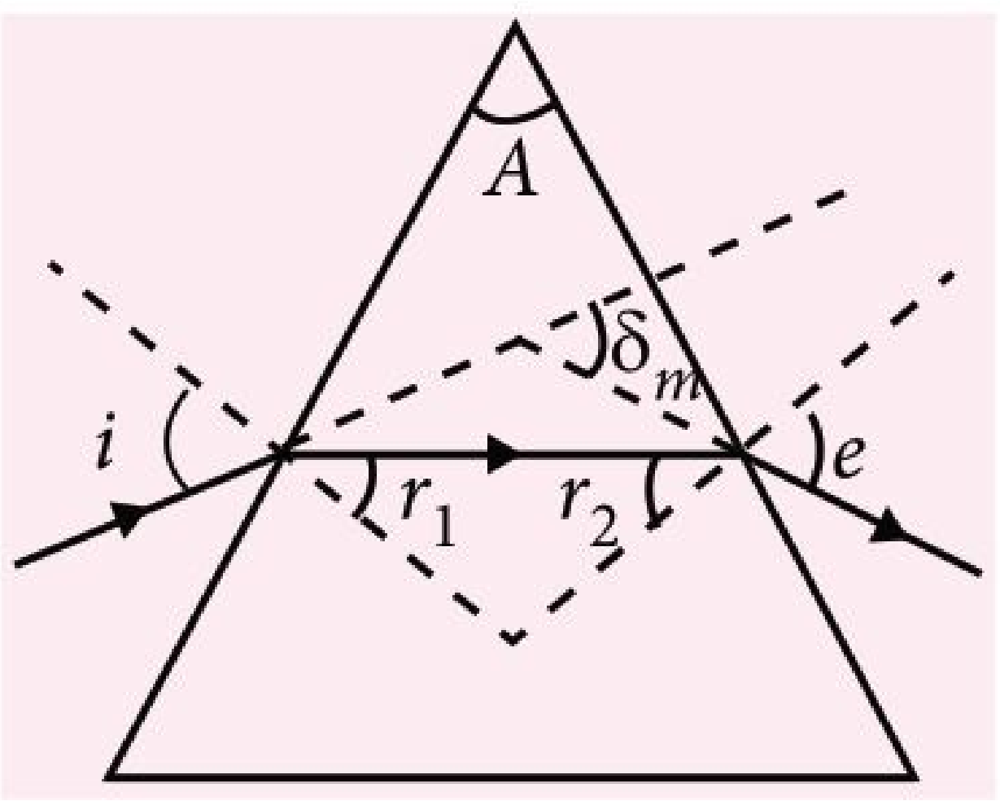
OR

In a parallel plate capacitor with plate area A and charge Q, what is the force on one plate because of the charge on the other?

35. Read the following paragraph and answer the questions.

Case Study : Prism Formula

Prism formula is used for accurate determination of refractive index of a transparent medium, of which the prism is made. Prism formula is derived using Snell's law.



The angle between incident ray and emergent ray is known as the angle of deviation. At the position of minimum deviation (δ_m) of a prism with angle of prism A as shown in figure, $i = e$ and $r_1 = r_2 = r$.

(i) Light rays from a source are incident on a glass prism of index of refraction μ and angle of prism α. At near normal incidence. Find the angle of deviation of the emerging rays.

(ii) When light rays are incident on a prism at an angle of 45°, the minimum deviation is obtained. If refractive index of material of prism is $\sqrt{2}$, then find angle of prism.

(iii) The angle of a prism is 30°. The rays incident at 60°, at one refracting face, suffers a deviation of 30°. Find the angle of emergence.

OR

For an equilateral prism of refractive index $\sqrt{3}$, if the ray is parallel to the base inside the prism, then what will be the angle of incidence?

SOLUTIONS

1.	**(c)**	**2.**	**(c)**	**3.**	**(b)**	**4.**	**(b)**
5.	**(a)**	**6.**	**(d)**	**7.**	**(c)**	**8.**	**(c)**
9.	**(a)**	**10.**	**(a)**	**11.**	**(b)**	**12.**	**(d)**
13.	**(b)**	**14.**	**(c)**	**15.**	**(b)**	**16.**	**(a)**
17.	**(a)**	**18.**	**(c)**				

19. de-Broglie wavelength of a charged particle accelerated through a potential difference V is given by, $\lambda = \dfrac{h}{\sqrt{2mqV}}$

$\therefore$ For proton and α particle charges are q and $2q$ respectively,

$$\therefore \quad \lambda_p = \frac{h}{\sqrt{2m_p qV}} \qquad \text{...(i)}$$

$$\lambda_\alpha = \frac{h}{\sqrt{4m_\alpha qV}} \qquad \text{...(ii)}$$

From eqn (i) and (ii)

$$\therefore \quad \frac{\lambda_\alpha}{\lambda_p} = \left(\frac{2m_p}{4m_\alpha}\right)^{1/2} = \frac{1}{2\sqrt{2}} \qquad (\text{As } m_\alpha = 4\,m_p)$$

20. (a) The essential condition, which must be satisfied for the sources to be coherent are :

(i) the two light waves should be of same wavelength.

(ii) the two light waves should either be in phase or should have a constant phase difference.

(b) Because coherent sources emit light waves of same frequency or wavelength and of a stable phase difference.

21. Change in current (ΔI) = (0.0 – 5.0) A = – 5.0 A

Time taken (Δt) = 100×10^{-3} s

Induced emf (ε) = 200 V

Induced emf (ε) is given by

$$\varepsilon = -\frac{\Delta\phi}{\Delta t} = -\frac{\Delta(LI)}{\Delta t} \quad \text{or} \quad \varepsilon = -L\frac{\Delta I}{\Delta t}$$

$$\text{or} \quad L = -\varepsilon\,.\,\frac{\Delta t}{\Delta I} = -\frac{(200).(100\times10^{-3})}{(-5.0)}$$

$L = 4.0$ H

OR

The magnetic energy is, $U_B = \dfrac{1}{2}LI^2$

$$= \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2 \qquad (\because\ B = \mu_0 nI, \text{ for a solenoid})$$

$$= \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2 = \frac{1}{2\mu_0}B^2 Al$$

The magnetic energy per unit volume is,

$$u_B = \frac{U_B}{V} \qquad (\text{where } V \text{ is volume that contains flux})$$

$$= \frac{U_B}{Al} = \frac{B^2}{2\mu_0}$$

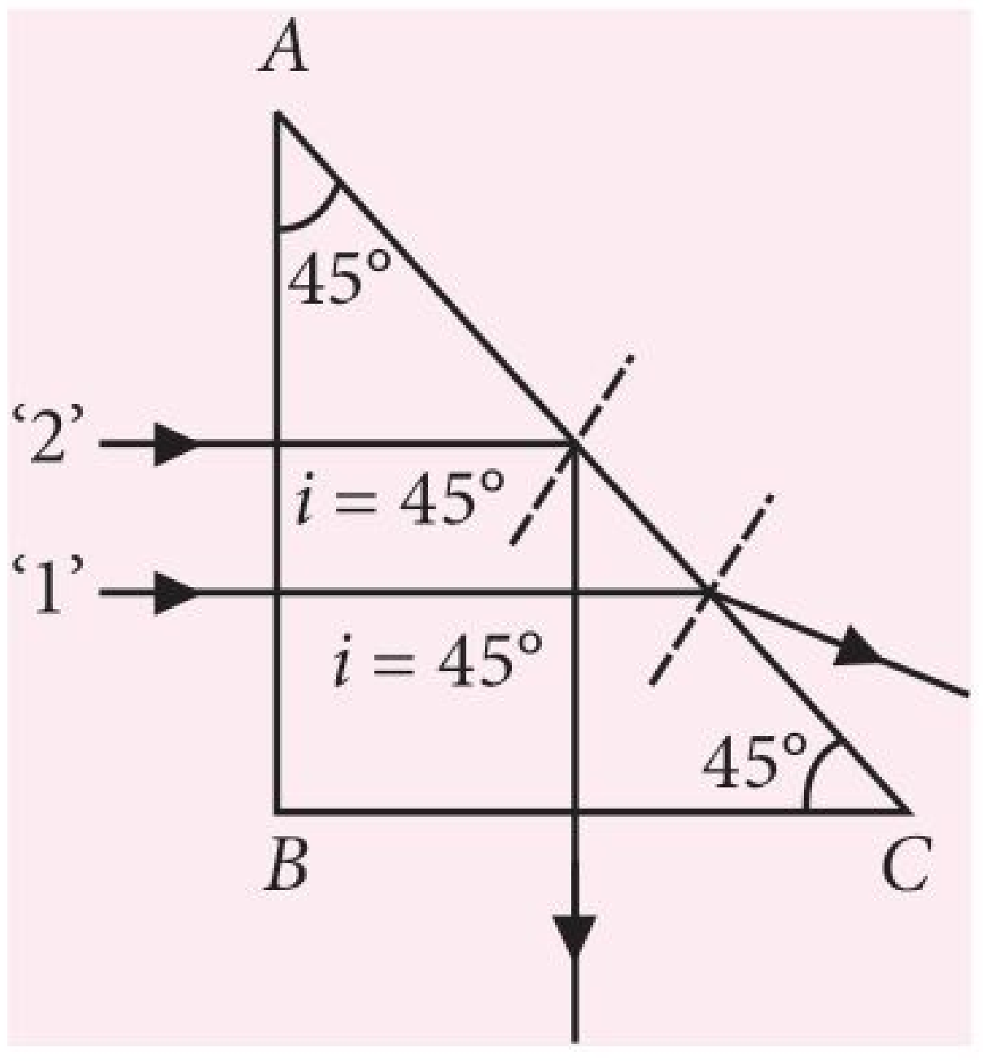
22. Critical angle for ray '1' : $\mu_1 = \dfrac{1}{\sin C_1}$

$$\sin C_1 = \frac{1}{\mu_1} = \frac{1}{1.33} = 0.75 \Rightarrow C_1 \approx 48^\circ$$

Critical angle for ray '2' : $\mu_2 = \dfrac{1}{\sin C_2}$

$$\sin C_2 = \frac{1}{\mu_2} = \frac{1}{1.45} = 0.69 \Rightarrow C_2 \approx 43^\circ$$

Both the rays will fall on the side *AC* with angle of incidence, *i* equal to 45°. Critical angle of ray '1' is greater than *i*. Hence, it will emerge from the prism as shown in the figure.



Critical angle of ray '2' is less than *i*. Hence, it will be internally reflected as shown in the figure.

23. (a) H_β line of Balmer series corresponding to the transition from $n = 4$ to $n = 2$ level. The corresponding wavelength for H_β line is,

$$\frac{1}{\lambda} = (1.097 \times 10^7)\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$= 0.2056 \times 10^7$ m

$\lambda = 4.9 \times 10^7$ m

(b) $f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{4.9 \times 10^{-7}} = 6.12 \times 10^{14}$ Hz

OR

For a controlled chain reaction, the average number of available neutrons should never exceed one per fission. Any excess neutrons over this critical unit should be absorbed. This is what the control rods do. They are made of cadmium because cadmium has a high cross-section for neutron absorption.

24. **(i)** Elements of earth's magnetic field :

(a) Angle of declination (θ)

(b) Angle of dip (δ)

(c) Horizontal component of earth's magnetic field (B_H)

(ii) At equator.

25. The work function of alkali metal is very low. Even the ordinary visible light can bring about emission of photoelectrons from these metals. Thus done to this reason, alkali metal surfaces are most suitable as photosensitive surfaces.

26. No, an increase in current sensitivity of a moving coil galvanometer may not necessary result in an increase in voltage sensitivity. As the number of turns (length of the coil) is increased to increase the current sensitivity of the device, the resistance of the coil changes. This is because the resistance of the coil is dependent on factors like length and area of a coil. As we know that voltage sensitivity

$\frac{\theta}{V} = \frac{(NAB/K)}{(1/R)}$; the average value remain uncharged.

27. **(i)** Bohr's quantization condition : The electron revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $h/2\pi$.

i.e., $L = mvr = n\frac{h}{2\pi}$; $n = 1, 2, 3, ...$

de-Broglie hypothesis may be used to derive Bohr's formula by considering the electron to be a wave spread over the entire orbit, rather than as a particle which at any instant is located at a point in its orbit. The stable orbits in an atom are those which are standing waves. Formation of standing waves require that the circumference of the orbit is equal

PUBLIC NOTICE

WBJEE 2023

The West Bengal Joint Entrance Examinations Board (WBJEEB) will conduct OMR based Common Entrance Examination WBJEE-2023 for admission in the academic session 2023-24 for Undergraduate Courses in Engineering/Technology, Pharmacy and Architecture of different Universities, Government Colleges as well as Self-Financing Engineering/Technological Institutes in the State of West Bengal.

Schedule of WBJEE-2023

Date of Examination	Paper/Subject	Time schedule
30/04/2023 **(Sunday)** (Tentative and may be changed in extra ordinary circumstances)	Paper-I (Mathematics)	11:00 a.m. to 1.00 p.m.
	Paper-II (Physics & Chemistry)	2:00 p.m. to 4:00 p.m.

The test will be held once in a year and there shall be no further examination under any circumstances for those who are unable to appear on the date and time mentioned above.

Pattern of Question Papers in WBJEE-2023

All questions will be **Multiple-Choice Questions (MCQ)**, with four options against each question. There will be three categories of questions in each subject. The number of questions as well as maximum marks for each are given in the following table:

Subject	**Category-1** Each Q carries 1 mark (–ve marks = –1/4)	**Category-2** Each Q carries 2 marks (–ve marks = –1/2)	**Category-3** Each Q carries 2 marks (No –ve marks)	Total Number of Questions	**Total Marks**
	No. of Q	No. of Q	No. of Q		
Mathematics	50	15	10	75	100
Physics	30	5	5	40	50
Chemistry	30	5	5	40	50

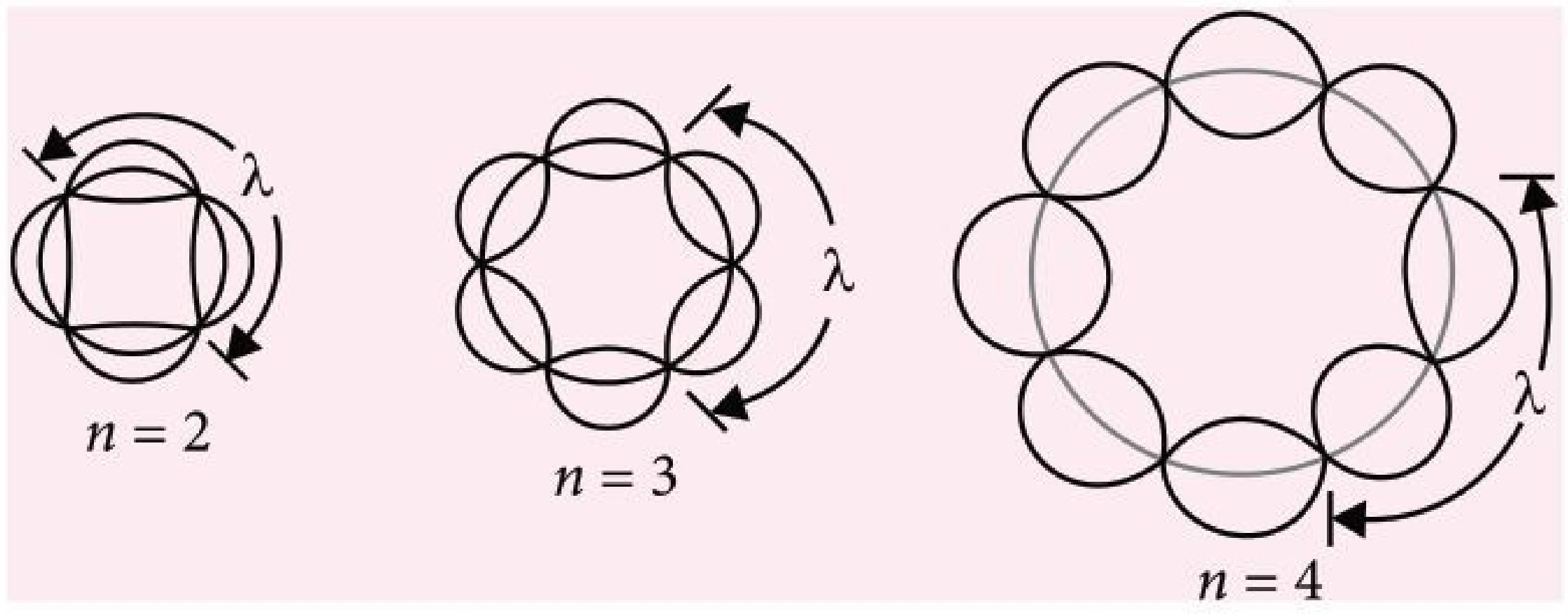
For more information, please visit the official website www.wbjeeb.nic.in

in length to an integral multiple of the wavelength. Thus, if r is the radius of the orbit

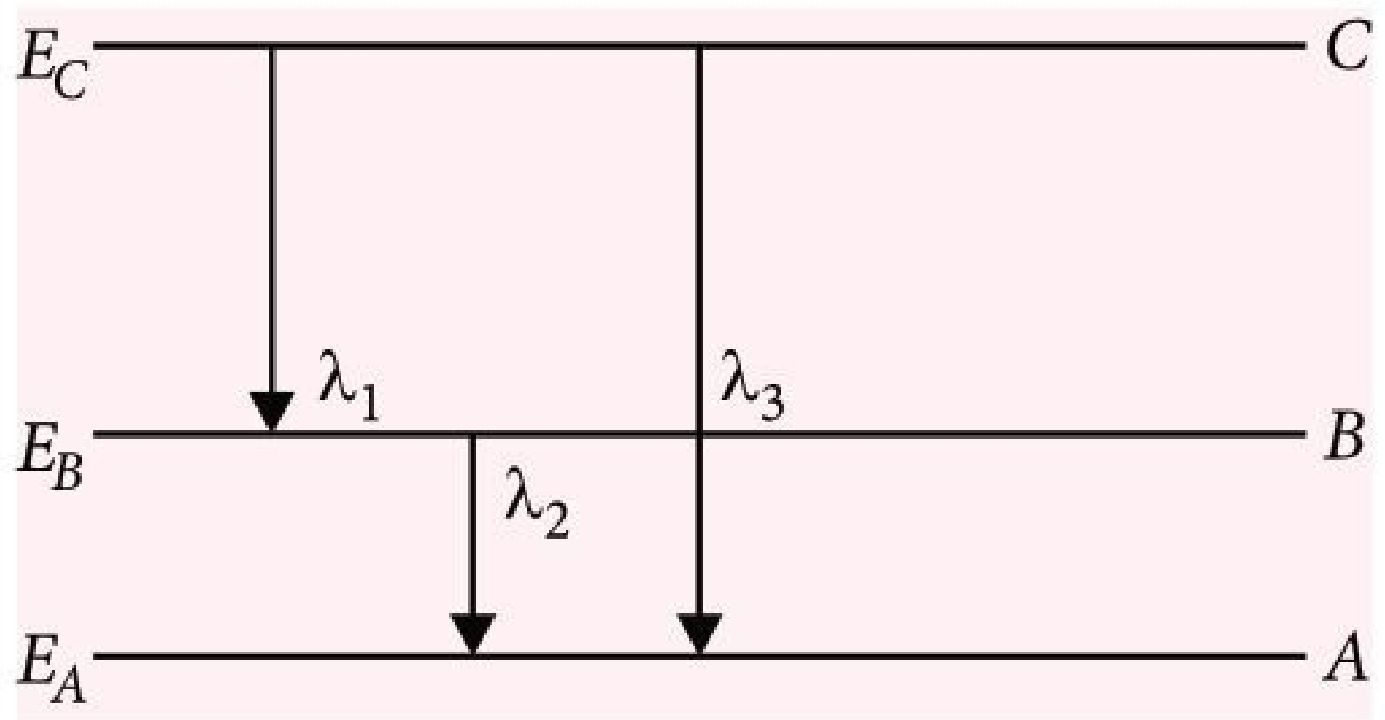
$$2\pi r = n\lambda = \frac{nh}{p} \qquad \left(\because\ \lambda = \frac{h}{p}\right)$$

which gives the angular momentum quantization.

$$L = pr = n\frac{h}{2\pi}$$



(ii)



Clearly, from energy level diagram,

$E_C - E_A = (E_C - E_B) + (E_B - E_A)$

(On the basis of energy of emitted photon).

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} \Rightarrow \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

which is the required relation between the three given wavelengths.

28. **(a)** Let resistance of iron wire at t°C

= Resistance of copper wire at t°C

$\therefore\ R_{Fe}[1 + \alpha(t - 20)] = R_{Cu}[1 + \alpha(t - 20)]$

$3.9[1 + 5.0 \times 10^{-3}(t - 20)]$

$= 4.1\,[1 + 4.0 \times 10^{-3}(t - 20)]$

$[3.9 \times 5 - 4.1 \times 4] \times 10^{-3} \times (t - 20) = 4.1 - 3.9$

$$t - 20 = \frac{0.2}{3.1 \times 10^{-3}} = 64.5$$

$t = 64.5 + 20 = 84.5$°C

(b) Given $E_1 = E_2 = E = 5$ V

and $r_1 = r_2 = r = 2\ \Omega$, and $R = 10\ \Omega$

Then current, $I = \dfrac{E_{eq}}{R + r_{eq}} = \dfrac{5}{10 + 2/2} = \dfrac{5}{11}$ A

$\therefore$ Voltage across the external resistance,

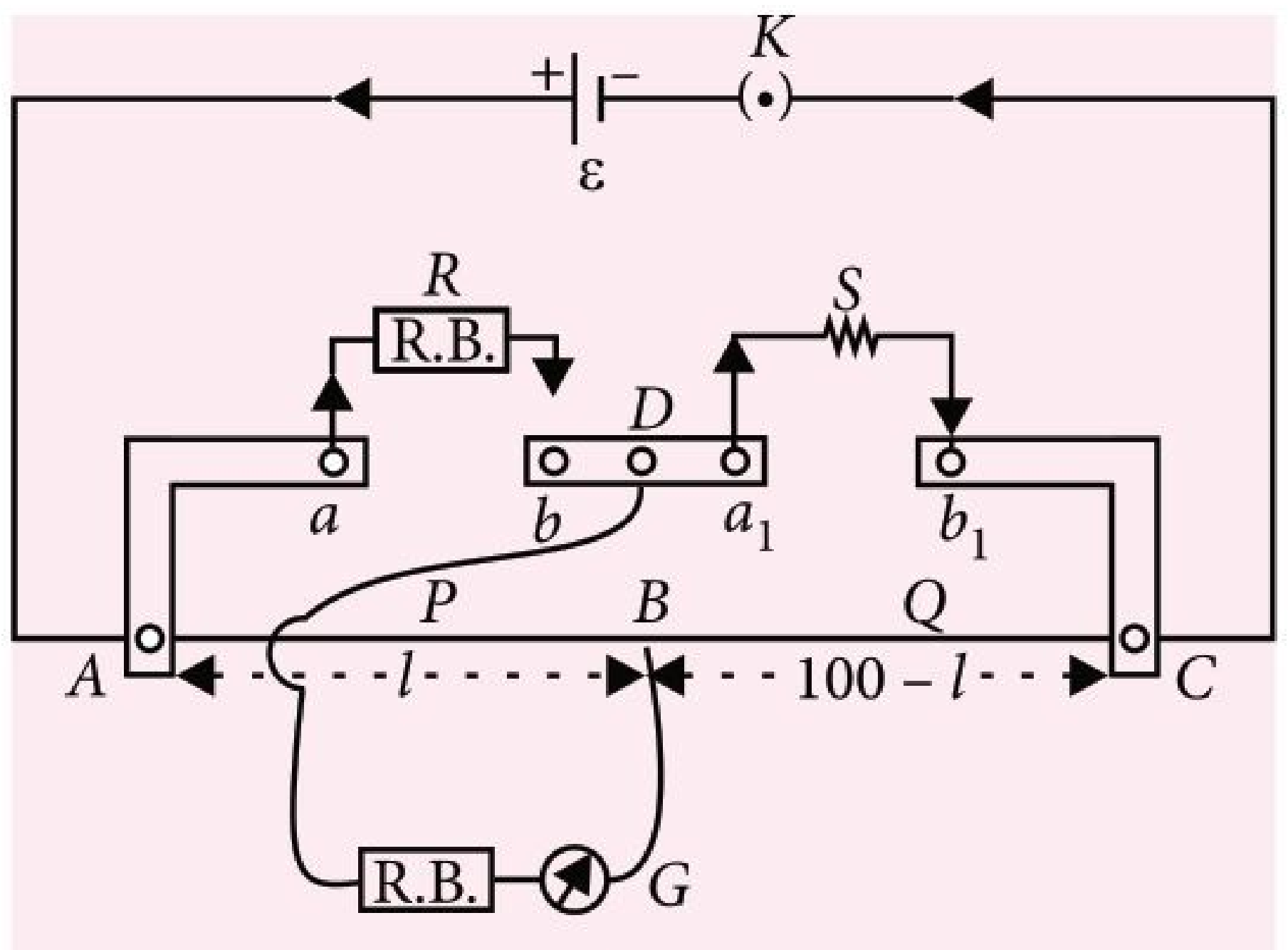
$$V = IR = \frac{5}{11} \times 10 = \frac{50}{11} = 4.55 \text{ V}$$

OR

Meter bridge : It is the simplest practical application of the Wheatstone bridge that is used to measure an unknown resistance.

Principle : Its working is based on the principle of Wheatstone bridge.

When the bridge is balanced, $\dfrac{P}{Q} = \dfrac{R}{S}$



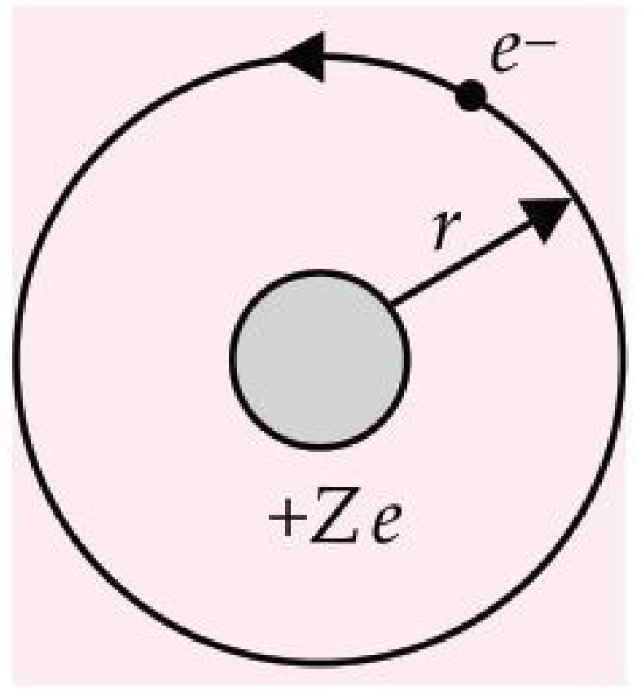
Measurement of unknown resistance by a meter bridge.

where unknown resistance, $S = \dfrac{R(100 - l)}{l}$

29. The electron of charge $(-e)$ performs uniform circular motion around a stationary heavy nucleus of charge $+Ze$. This constitutes a current I and forms a loop which behaves like a tiny magnetic dipole.

$I = \dfrac{e}{T}$ (T = time period) ...(i)

Let r be the orbital radius of the electron and v the orbital speed. Then,



$T = \dfrac{2\pi r}{v}$ ...(ii)

From eqn (i) and (ii),

$I = ev/2\pi r$

Magnetic moment $\mu = I\pi r^2 = evr/2$

The direction of magnetic moment is into the plane of paper.

Now, $\mu = \dfrac{e}{2m_e}(m_e vr) = \dfrac{e}{2m_e}L$

where L is the magnitude of angular momentum of the electron.

Vetorially, $\vec{\mu} = \dfrac{-e}{2m_e}\vec{L}$

The negative sign indicates that the angular momentum of the electron is opposite in direction to the magnetic moment.

OR

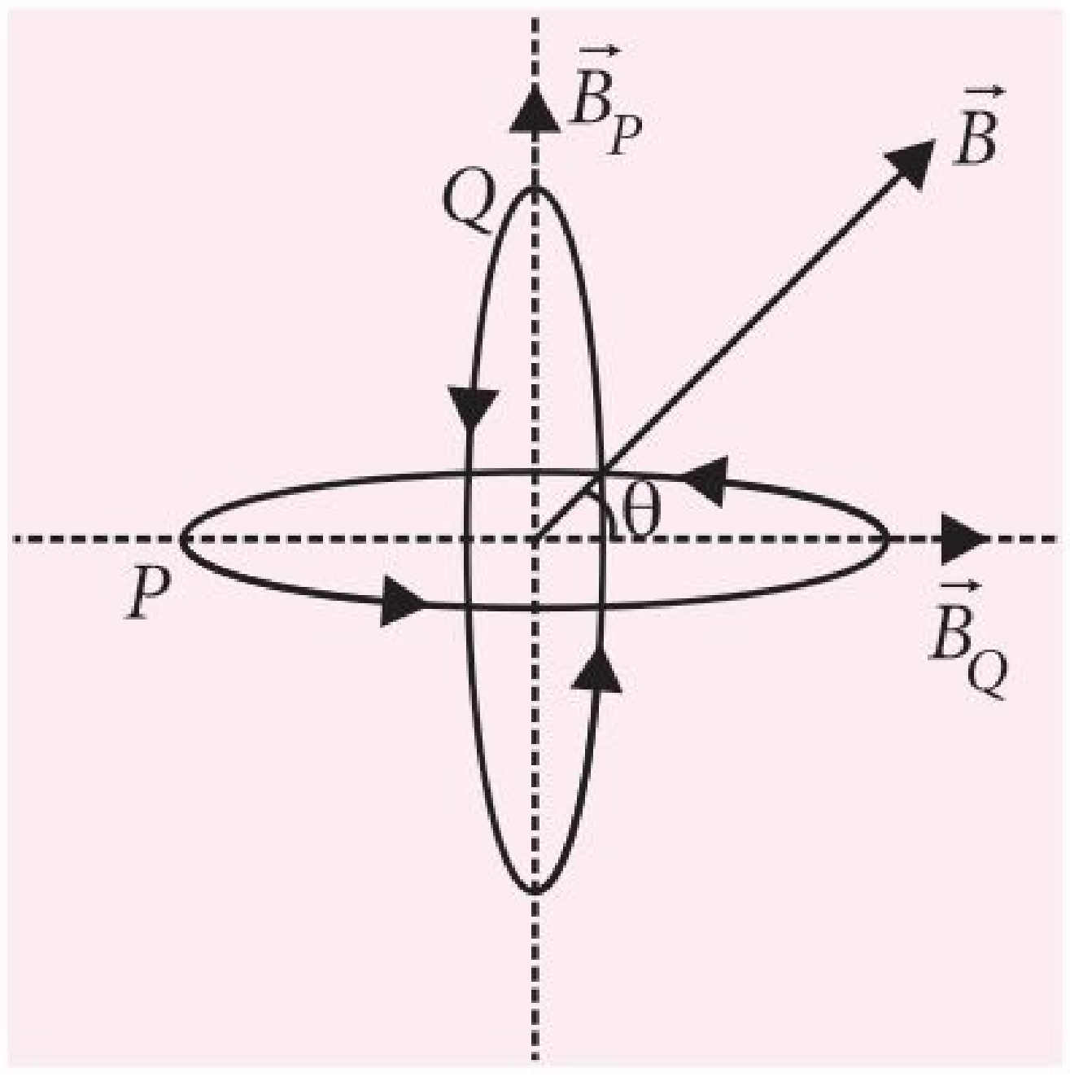
Magnetic field at the centre of the coils due to coil P, having current I is

$$B_P = \frac{\mu_0 I}{2R}$$

And magnetic field due to coil Q having current $\sqrt{3}I$ is

$$B_Q = \frac{\mu_0 \sqrt{3} I}{2R}$$

Since both coils are inclined to each other at an angle of 90°, the magnitude of their resultant magnetic field at the common centre will be



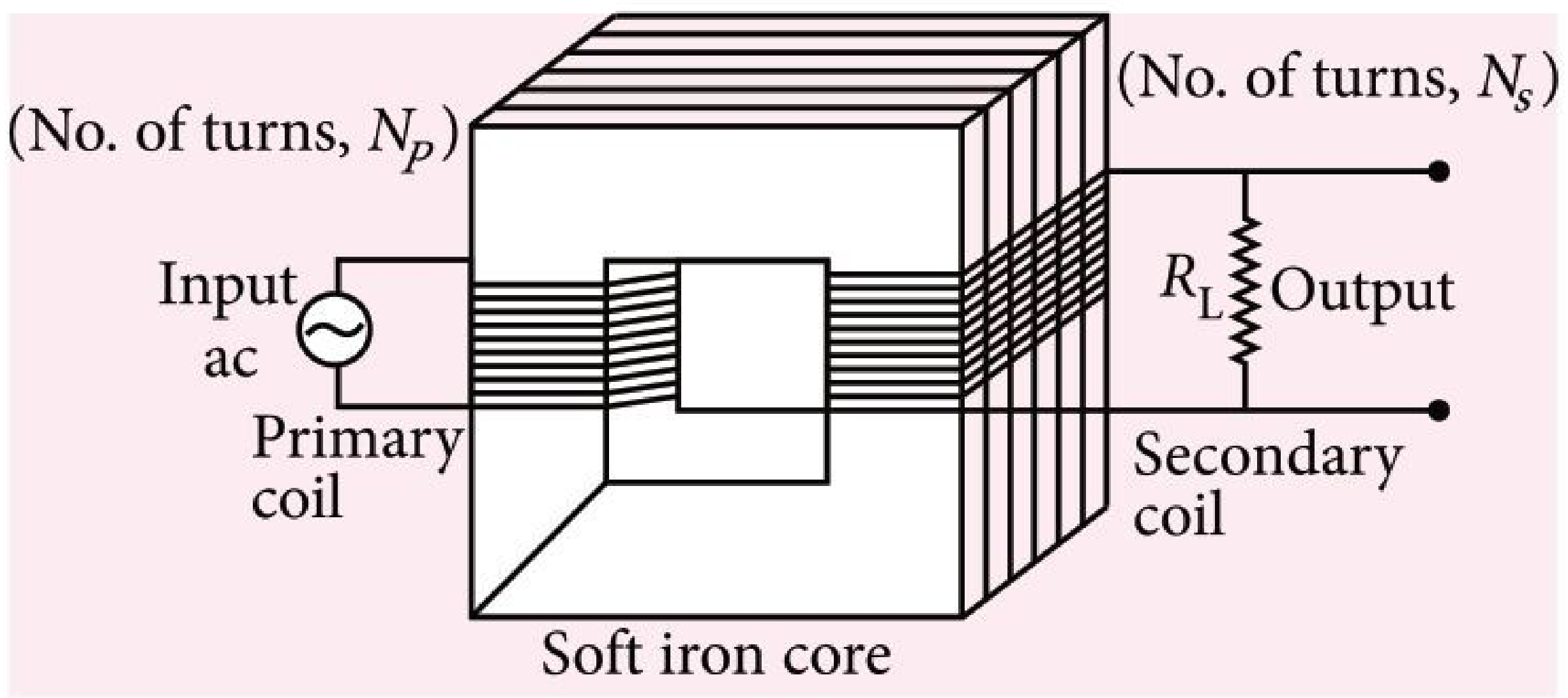
$$B = \sqrt{B_P^2 + B_Q^2} = \frac{\mu_0 I}{2R}\sqrt{1+3} = \frac{\mu_0 I}{R}$$

The directions of B_P and B_Q are as indicated in the figure. The direction of the resultant field is at an angle θ given by

$$\theta = \tan^{-1}\left(\frac{B_P}{B_Q}\right) = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$$

Hence, the direction of the magnetic field will be at an angle 30° to the plane of loop P.

30. Step-up transformer (or transformer) is based on the principle of mutual induction.



An alternating potential (V_p) when applied to the primary coil induced an emf in it.

$$\varepsilon_p = -N_p \frac{d\phi}{dt}$$

If resistance of primary coil is low $V_p = \varepsilon_p$.

i.e., $V_p = -N_p \dfrac{d\phi}{dt}$

As same flux is linked with the secondary coil with the help of soft iron core due to mutual induction, emf is induced in it. $\varepsilon_s = -N_s \dfrac{d\phi}{dt}$

If output circuit is open $V_s = \varepsilon_s$

$V_s = -N_s \dfrac{d\phi}{dt}$. Thus $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$

For an ideal transformer, $P_{\text{out}} = P_{\text{in}}$

$$I_s V_s = I_p V_p \qquad \therefore \frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$$

For step-up transformer $N_s > N_p$

In case of dc voltage, flux does not change. Thus no emf is induced in the circuit.

(i) The core of the transformer is laminated to reduce eddy current losses.

(ii) Thick copper wire is used in windings of transformers because of its low resistivity *i.e.*, low resistance.

31. *Refer to answer 22, Page no. 613, Class-12, MTG 100 percent Physics.*

OR

Refer to answer 24, Page no. 623, Class-12, MTG 100 percent Physics.

32. *Refer to answer 21, Page no. 413, Class-12, MTG 100 percent Physics.*

OR

Refer to answer 20, Page no. 412-413, Class-12, MTG 100 percent Physics.

33. *Refer to answer 15, Page no. 135, Class-12, MTG 100 percent Physics.*

OR

Refer to answer 26, Page no. 147-148, Class-12, MTG 100 percent Physics.

34. **(i)** The net energy stored in the two capacitors will be less than the sum of the initial individual energies.

(ii) The capacitance of a parallel plate capacitor having a medium of permittivity ε between the plates is

$$C = \frac{\varepsilon A}{d} \qquad \text{...(i)}$$

where d is the distance between the plates and A is the area of each plate.

When the medium of this capacitor is replaced by another medium of permittivity $\dfrac{\varepsilon}{2}$, then its capacitance becomes

$$C' = \frac{\varepsilon}{2}\frac{A}{d} = \frac{1}{2}\left(\frac{\varepsilon A}{d}\right) = \frac{C}{2} \qquad \text{(Using (i))}$$

UNSCRAMBLED WORDS

DECEMBER 2022

1-h- FERROMAGNETIC
2-g- ELECTROMAGNETIC
3-a- VENTURIMETER
4-i - CYLINDRICAL
5-j- RAYLEIGH
6-d- IMPULSE
7-c- ELECTROSTATICS
8-b- ZENER
9-e- POTENTIOMETER
10-f- DECAPOISE

Winners: *R. Phani Kumar (Andhra Predesh), Seikh Sayed Aaman (West Bengal)*

(iii) $E = 10^5$ V/m, $q = 1\ \mu\text{C} = 10^{-6}$ C,

$$F = \frac{q^2}{2\varepsilon_0 A} \text{ and } E = \frac{q}{\varepsilon_0 A}$$

$$\therefore\ F = \frac{qE}{2} = \frac{10^{-6}\times 10^{5}}{2} = 0.05\ \text{N}$$

OR

The electric field on one plate due to the charge on the other is $E = \dfrac{Q}{2A\varepsilon_0}$

$\therefore$ The force on one plate due to the charge on the other is

$$F = QE = Q\left(\frac{Q}{2A\varepsilon_0}\right) = \frac{Q^2}{2A\varepsilon_0}$$

35. (i) For prism

Deviation δ = angle between emergent and incident rays.

Angle of prism = $A = \alpha$,

$\therefore\ \delta = (\mu - 1)\,\alpha$

(ii) $$\mu = \frac{\sin\left(\dfrac{A+\delta}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}$$

where δ denotes minimum deviation.

In minimum deviation position, $i = \left(\dfrac{A+\delta}{2}\right)$;

$$45^\circ = \left(\frac{A+\delta}{2}\right)$$

$$\therefore\ \mu = \frac{\sin 45^\circ}{\sin\left(\dfrac{A}{2}\right)} \Rightarrow \sqrt{2} = \frac{1}{\sqrt{2}\cdot\sin\left(\dfrac{A}{2}\right)}$$

$$\Rightarrow \sin\left(\frac{A}{2}\right) = \frac{1}{2} = \sin 30^\circ \Rightarrow A = 60^\circ.$$

(iii) Here $i + e = A + \delta - i$

or $e = 30^\circ + 30^\circ - (90^\circ - 60^\circ)$ $(\because i = 90^\circ - 60^\circ)$

or $e = 30^\circ$.

OR

Since prism is equilateral, therefore angle of prism $A = 60^\circ$ and $r_1 + r_2 = A$

For minimum deviation, $r_1 = r_2$

$$\therefore r_1 = \frac{A}{2} = \frac{60}{2} = 30^\circ$$

Using, $$\mu = \frac{\sin i}{\sin r_1} = \sqrt{3} = \frac{\sin i}{\sin 30^\circ} \Rightarrow i = 60^\circ$$

◆ ◆

UNSCRAMBLE ME

Unscramble the words given in column I and match them with their explanations in column II.

Column I		Column II
1. SROLENDY MBUNRE	(a)	Reciprocal of Bulk Modulus.
2. OLETVTMRE	(b)	Device used to convert AC into DC.
3. ORSBLCMPEISITIY	(c)	The points at which the amplitude is largest in standing waves.
4. ONEVCSTERAIV	(d)	The another name of angle of dip.
5. EVKLNI	(e)	Slope of the tangent of velocity-time graph at an instant.
6. OALICINITN	(f)	It is connected in parallel with the circuit always.
7. IRWEVOMCA	(g)	A number which determines the nature of flow of liquid through a pipe.
8. DNIATONSE	(h)	The waves which are used in satellite signals.
9. ETIIRFERC	(i)	It is the fraction 1/273.16 of the thermodynamic temperature of triple point of water.
10. CELAACERITNO	(j)	Nature of electrostatic force.

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

Be Lab READY!

Class XII

Experiment-1

AIM

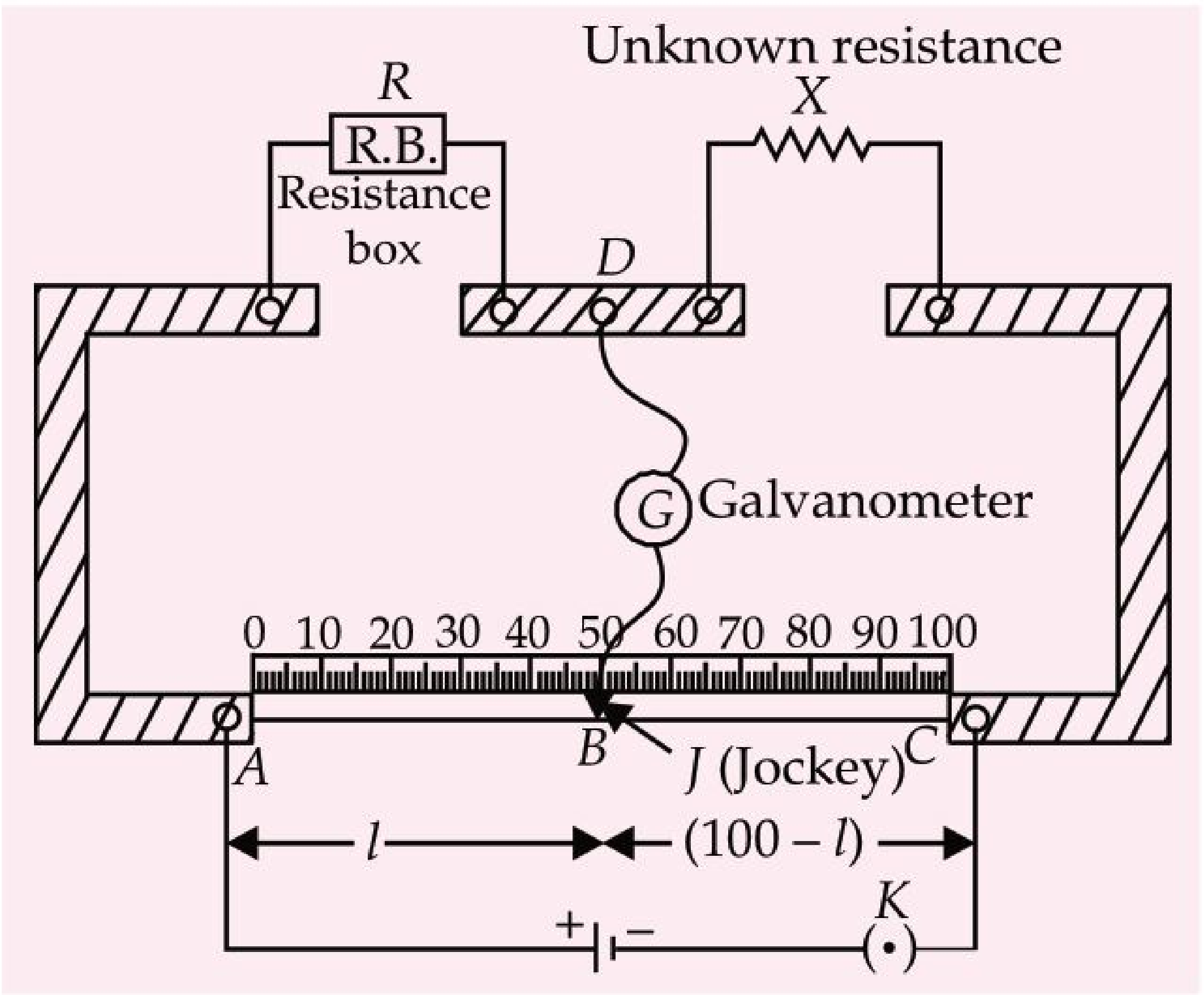
To find resistance of a given wire/standard wire using a metre bridge.

APPARATUS REQUIRED

A metre bridge, a Leclanche cell, a galvanometer, resistance box, a jockey, a one-way key, a resistance wire, a screw gauge, a metre scale, a set square, connecting wires, sand paper, etc.

CIRCUIT DIAGRAM

The circuit diagram to determine resistivity of the material of a given wire using metre bridge is shown in the figure below.



PROCEDURE

1. The arrangement of the apparatus should be as shown in the circuit diagram.
2. The wire whose resistance is to be determined should be connected in the right gap between C and B without any formation of loops.
3. The resistance box should be connected in the left gap between A and B.
4. All the other connections should be as shown in the circuit diagram.
5. Plug the key K in place of 2 ohm resistance in the resistance box.
6. The jockey should be first touched gently to the left end and then to the right end of the bridge.
7. The deflections in the galvanometer should be in opposite directions and if it is in one direction then the circuit connections are not correct. Note the galvanometer deflection.
8. Let D be the null point where the jockey is touching the wire. The movement of the jockey should be gentle from left to the right of the galvanometer.
9. Adjust the resistance from the resistance box such that when the jockey is nearly in the middle of the wire, there shouldn't be any deflection.
10. Note the position of D to know the length of AB and BC.
11. Four sets of observations should be taken by changing the value of R.
12. Record the observations in a tabular form.
13. Stretch the resistance wire to find its length using a metre scale.
14. Using screw gauge, measure the diameter of the wire at four different places keeping it in a mutually perpendicular direction.
15. Record the observations in the table.

OBSERVATIONS

Length of given wire, $l = \ldots.$ cm

Table 1 : For determining the unknown resistance (X)

Resistance from box, R (Ohm)	Length $AB = l$ (cm)	Length $BC =$ (100-l (cm)	Unknown Resistance $X = \frac{R(100-l)}{l}$ (Ohm)

Least count of the screw gauge (L.C.) = ... mm

Total no.of divisions on the circular scale =

Least count of the given screw gauge

$$= \frac{\text{Pitch}}{\text{No. of divisions on the circular scale}} = \ldots \text{ mm}$$

Zero error of the screw gauge = ... mm

Table 2 : For the measurement of diameter of the wire.

Main scale reading p(mm)	Coinciding circular scale division n	Total reading $d_1 = p + n \times$ L.C) (diameter) (mm)	Mean $d = \frac{d_1 + d_2}{2}$ (mm)	Mean radius (d/2) (mm)

CALCULATIONS

Calculation for X :

The value of l is determined from the position of D and recorded in column 2 of Table 1.

Find length (100 - l) and write in column 3.

Calculate unknown resistance X and write in column 4,

$$\text{Mean } X = \frac{X_1 + X_2 + X_3 + X_4}{4} = \ldots.. \text{ ohm}$$

RESULT

The value of unknown resistance X = ... ohm

Viva-Voce

1. Why is the metre bridge called so?
2. What is the null point?
3. Why is the bridge method better than the Ohms law of measurement?
4. What is the range of measurement of resistance using a Wheatstone bridge?
5. How can a Wheatstone bridge be used for the measurement of physical parameters?

Solutions

1. It is called a metre bridge because the bridges use one-meter long wire.
2. Null point is defined as the point at which a galvanometer reads zero deflections.
3. Bridge method is better than the Ohm's law of measurement because of the null method.
4. The resistance measurement range using a Wheatstone bridge is between 1 Ω to a few megaohms.
5. Wheatstone bridge can be used to measure the physical parameters like temperature, light, etc, using operational amplifier and rectifiers for the conversion of A.C to D.C.

Experiment-2

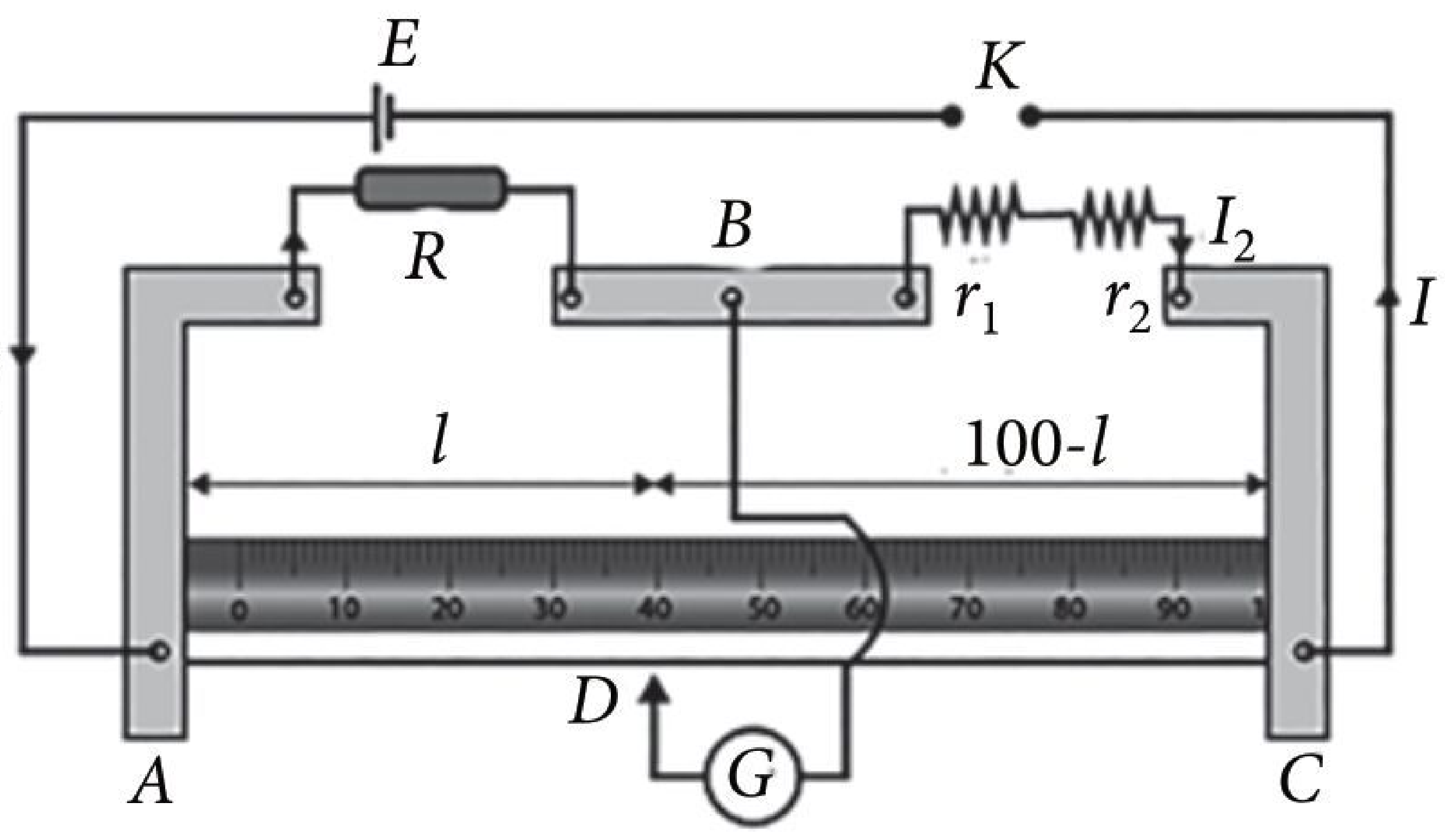
AIM

To verify the laws of the combination (series) of resistances using a meter bridge.

APPARATUS REQUIRED

Meter Bridge, Leclanche cell, Resistance box, Galvanometer, Jockey, Sand Paper, Connecting wire, Two resistance wires, a set square, etc.

CIRCUIT DIAGRAM



PROCEDURE

1. Mark the two resistance coils as r_1 and r_2.
2. To find the value of r_1 and r_2, follow the same steps as experiment 1.
3. Connect two coils r_1 and r_2 in series as shown in the figure.
4. Record the observations as given in the table below.

OBSERVATIONS

Resistance coil	S. No. of Observations	Resistance from the resistance box	Length $AD = l$ cm	Length $DC =$ $(100 - l)$ cm	Resistance $r = \frac{(100-l)}{l} \cdot R$	Mean Resistance (ohm)
r_1 only	1. 2. 3.					$r_1 =$ ....
r_2 only	1. 2. 3.					$r_2 =$ ....
r_1 and r_2 in series	1. 2. 3.					$R_s =$ ....

RESULT

Within limits of experimental error, theoretical and experimental values of R are the same. Hence, the law of resistances in series is verified.

Viva-Voce

1. What is a metre bridge?
2. How do you find the equivalent resistance of the series combination of resistance?
3. What is preferable to connect bulbs in series or in parallel?
4. In which combination of resistance, total resistance is greater than the largest resistance in the circuit?
5. What is ohm? Define it.

Solution

1. A metre bridge, also called a slide wire bridge, is an instrument that works on the principle Wheatstone bridge. A meter bridge is used in finding the unknown resistance of a conductor as that of in a Wheatstone bridge
2. In series combination, the same current passes through each resistor in the chain and the total resistance R_S is given by the equation
$R_S = R_1 + R_2 + R_3 + ...$
3. Bulbs are connected in parallel so that even if one of the bulbs blow out, the other bulbs continue to get current supply.
4. In series combination of the resistance
5. Ohm is the SI unit of resistance. One ohm is the resistance offered by a conductor when one ampere current is flowing through it, when one volt potential difference is maintained across its ends.

Contributed by : Nitin Moolri, (Mohali, Punjab)

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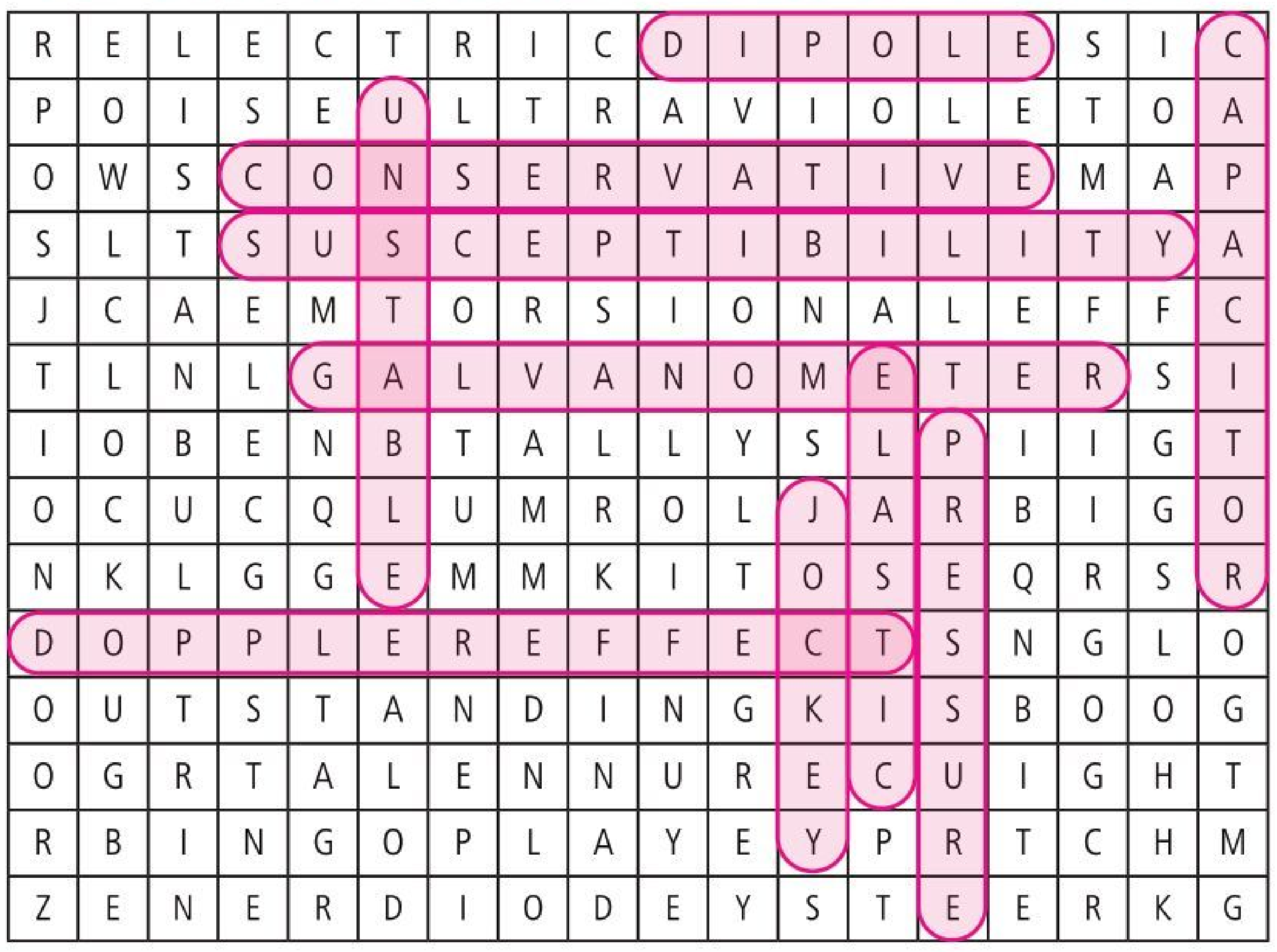


R	E	L	E	C	T	R	I	C	D	I	P	O	L	E	S	I	C
P	O	I	S	E	U	L	T	R	A	V	I	O	L	E	T	O	A
O	W	S	C	O	N	S	E	R	V	A	T	I	V	E	M	A	P
S	L	T	S	U	S	C	E	P	T	I	B	I	L	I	T	Y	A
J	C	A	E	M	T	O	R	S	I	O	N	A	L	E	F	F	C
T	L	N	L	G	A	L	V	A	N	O	M	E	T	E	R	S	I
I	O	B	E	N	B	T	A	L	L	Y	S	L	P	I	I	G	T
O	C	U	C	Q	L	U	M	R	O	L	J	A	R	B	I	G	O
N	K	L	G	G	E	M	M	K	I	T	O	S	E	Q	R	S	R
D	O	P	P	L	E	R	E	F	F	E	C	T	S	N	G	L	O
O	U	T	S	T	A	N	D	I	N	G	K	I	S	B	O	O	G
O	G	R	T	A	L	E	N	N	U	R	E	C	U	I	G	H	T
R	B	I	N	G	O	P	L	A	Y	E	Y	P	R	T	C	H	M
Z	E	N	E	R	D	I	O	D	E	Y	S	T	E	E	R	K	G

Across	Down
1. Conservative	1. Elastic
2. Dipols	2. Unstable
3. Galvanometer	3. Capacitor
4. Susceptibility	4. Jockey
5. Doppler effect	5. Pressure

Experiment-3

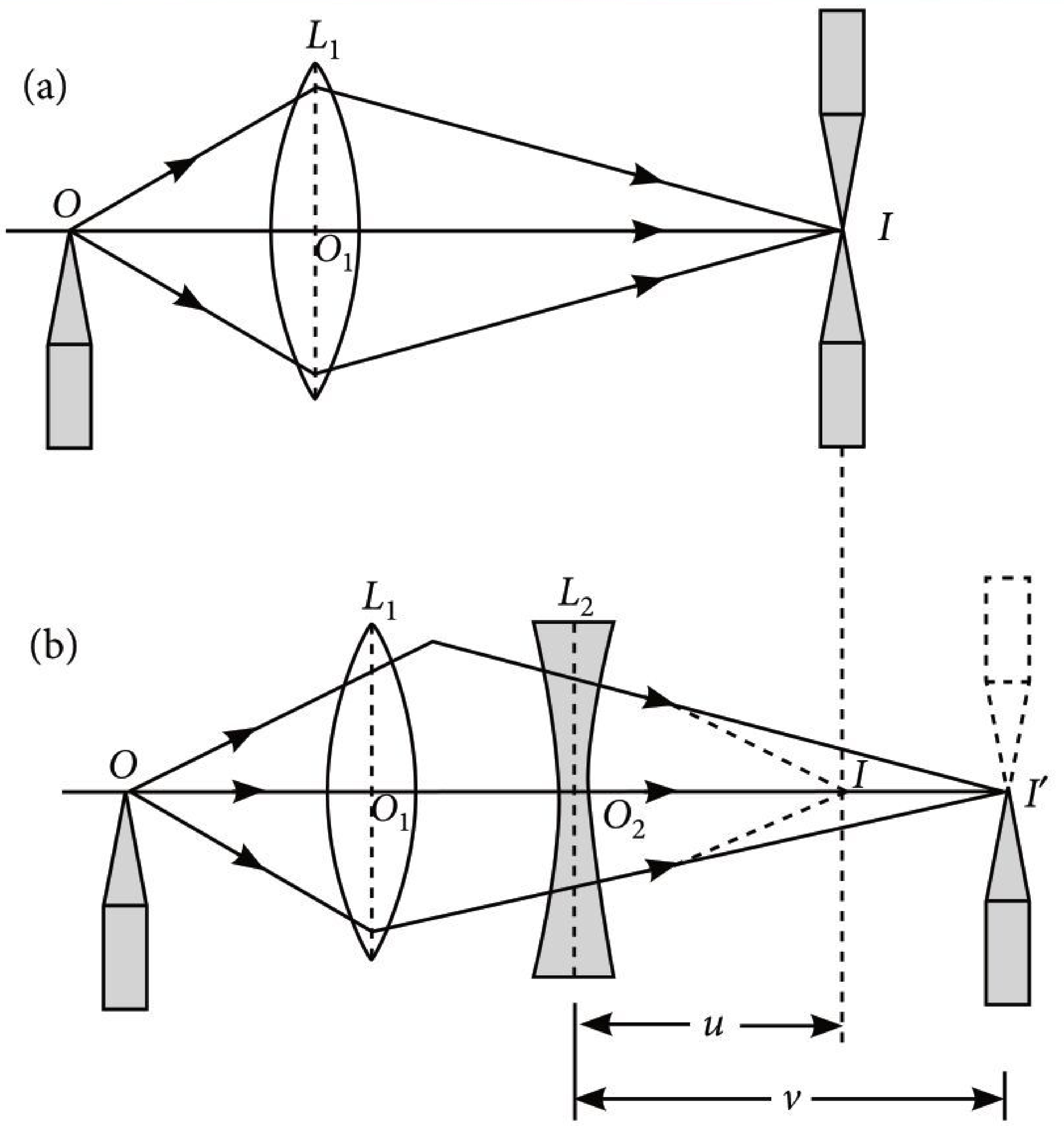
AIM

To find the focal length of a concave lens using a convex lens.

APPARATUS REQUIRED

An optical bench with four uprights a convex lens with a lens focal length, concave lens with a more focal length, two lens holders, one thick and one thin optical needle, knitting needle, a half-metre scale, etc.

RAY DIAGRAM



PROCEDURE

To determine the rough focal length of the convex lens :

1. Place the convex lens on the lens holder.
2. Now face the lens towards a distant tree or building.
3. Obtain the image either on the white wall or on a screen and keep moving the lens either forward or backwards till a sharp image is formed.
4. To determine the rough focal length of the lens, measure the distance between the lens and the screen.

To set the convex lens :

1. Place the lens on the holder with fixed upright such that the upright is kept at 50 cm mark.
2. The lens should be placed in such a way that its surface is vertical and perpendicular to the length of the optical bench.
3. The upright should be kept in this position throughout.

To set the object needle :

1. Place the thin optical needle which is the object needle *O* near-zero end of the upright which is moveable.
2. Place the object needle upright at a distance nearly 1.5 times the focal length of the lens.
3. The tip of the needle should be horizontal to the optical centre of the lens.
4. Note the position of the index mark below the object needle upright.
5. To see an inverted and enlarged image of the object needle which is in the middle of the lens, close the left eye and see with a right eye open.
6. On the other end of the optical bench, place the image needle on the fourth upright.
7. The tip of the image needle should be in line with the image that is seen with the right eye.
8. To see the parallax, move the eye towards the right. The image needle and object needle are no longer in line.
9. Remove the parallax tip to tip.
10. Note the position of the index mark at the base of the image needle upright.
11. Record the position of the index marks.
12. Now place the concave lens holder on the *I* side of the convex lens.
13. The upright and convex lens should be placed at a distance from each other.
14. The concave lens should be placed such that it coincides with the principal axes.

To set the image needle at *I′*:

1. Repeat steps 4 and 5.

To get more observations :

1. Repeat the experiment by moving the object needle towards the lens by 2 cm.
2. Repeat the experiment by moving the object needle away from the lens by 2 cm.
3. Record all the observations.

OBSERVATIONS

The rough focal length of a convex lens = ...

The actual length of the knitting needle, x = ...

Observed distance between the concave lens and image = ...

Needle when knitting needle is placed between them, y = ...

Index correction for u as well as v, $x - y = u$, v and f =........

Table for *u*, *v* and *f*

Position of						Observed		Corrected		
S.N.	O in cm	L_1 at O_1 in cm	I in cm	L_2 at O_2 in cm	I' in cm	$u = IO_2$ in cm	$v = I'O_2$ in cm	u in cm	v in cm	$f = \frac{uv}{u-v}$ in cm
1.										$f_1 =$
2.										$f_2 =$
3.										$f_3 =$

CALCULATIONS

1. To find observed u by finding the difference of position of L_2 and I.
2. To find observed v by finding the difference of position of L_2 and I'.
3. Corrected values of u and v are obtained by applying index correction.
4. Calculate, $f = \frac{uv}{u-v}$
5. Finding the mean of f, Mean $F = \frac{f_1 + f_2 + f_3}{3}$

RESULT

The focal length of the given concave lens = ... cm

Viva-Voce

1. What is a spherical lens?
2. What type of lens is present in the human eye?
3. What are the factors affecting the power of lens?
4. What is the focal length of a lens?
5. What are the use of lens?

Solution

1. Spherical lens is defined as a lens that is part of a sphere and has a surface that is spherical.
2. Convex lens is present in human eye.
3. Following are the factors affecting the power of lens:
   (i) Refractive index of the material used in the lens.
   (ii) The change in medium.
   (iii) The radius of curvature.
   (iv) The wavelength of the light.
   (v) The thickness of the lens.
4. The focal length of a lens is defined as the distance between the optical centre and the principal focus of the lens.
5. Lenses are used in spectacles, microscopes, in optical instruments, and in telescopes.

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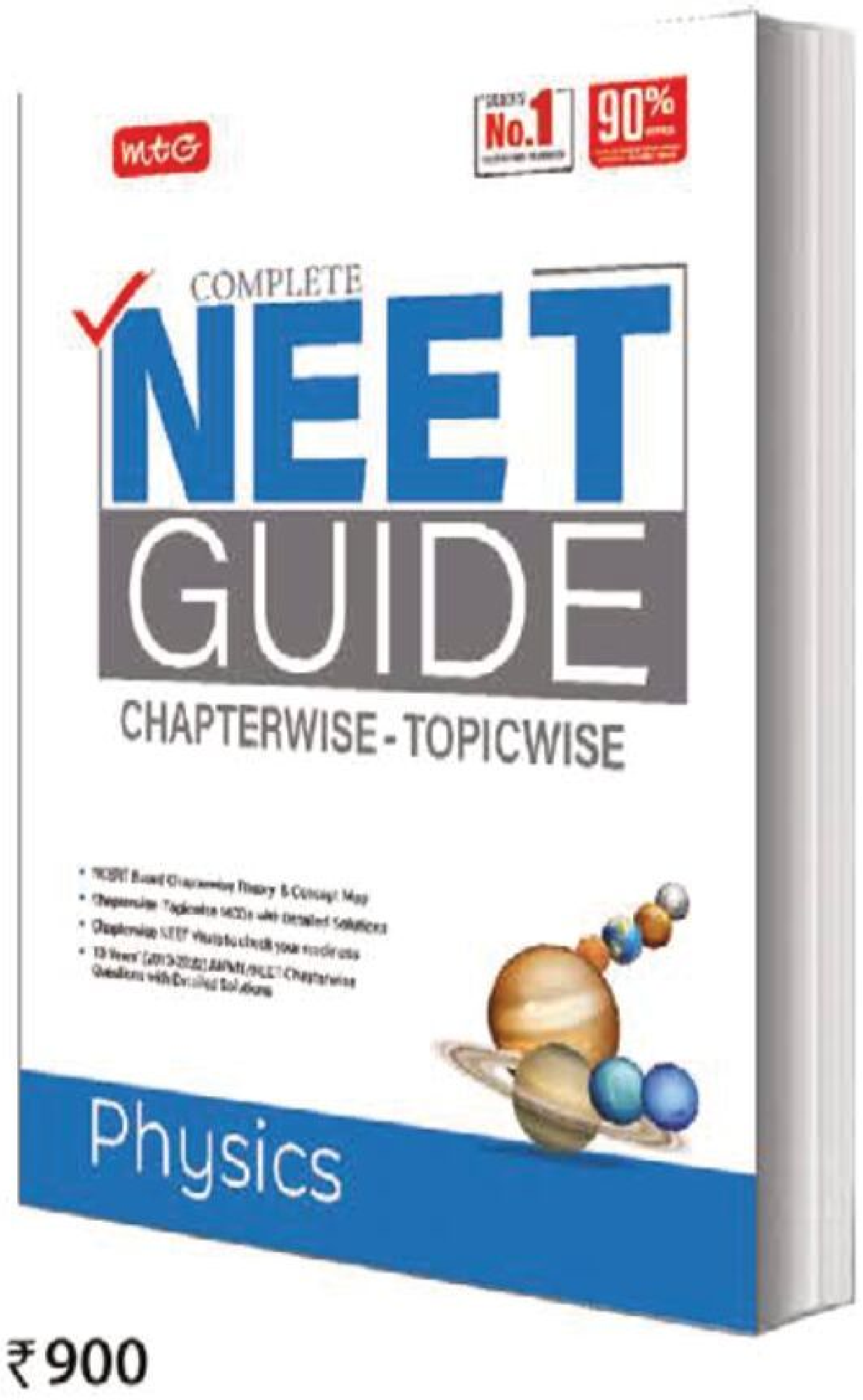

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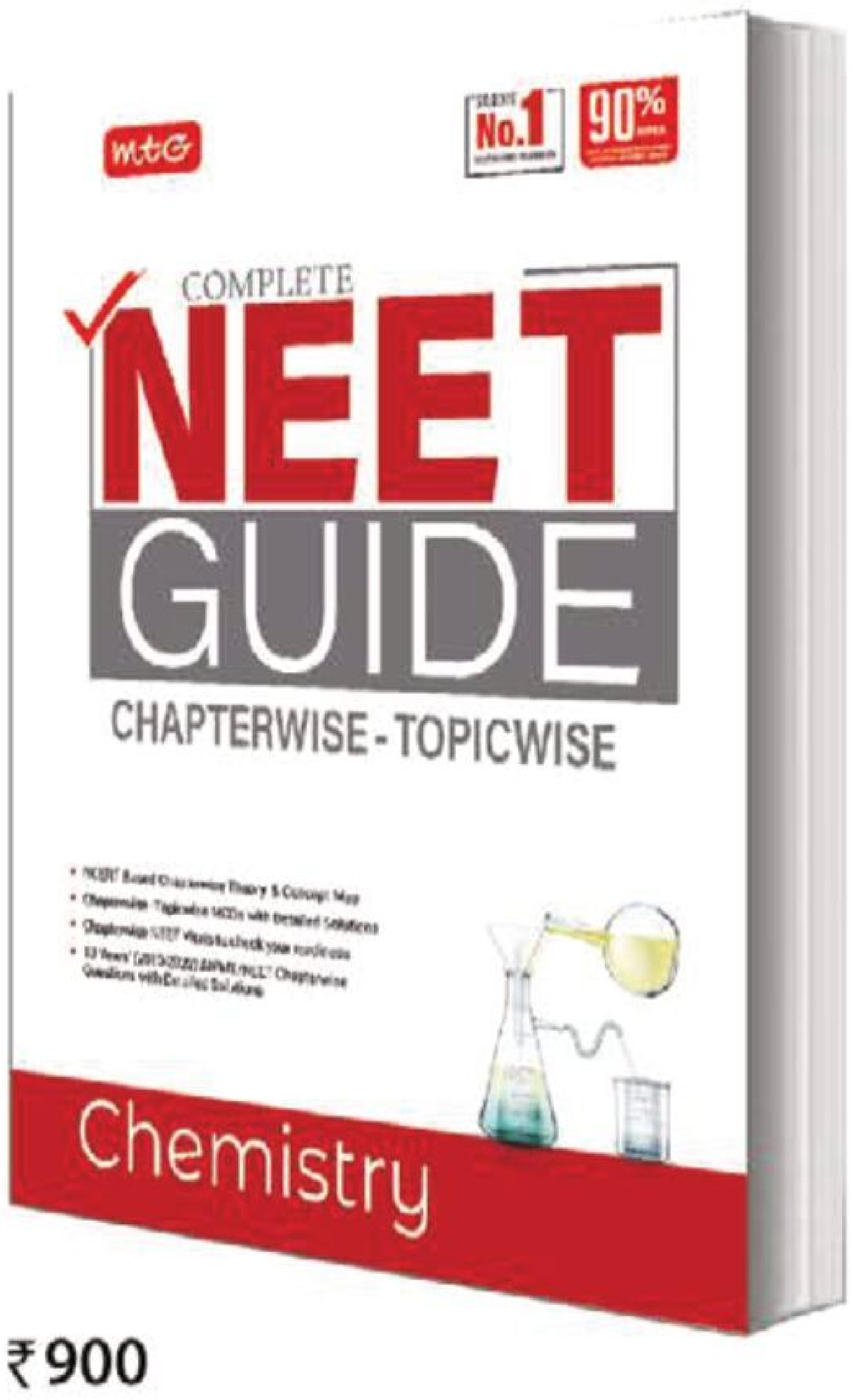

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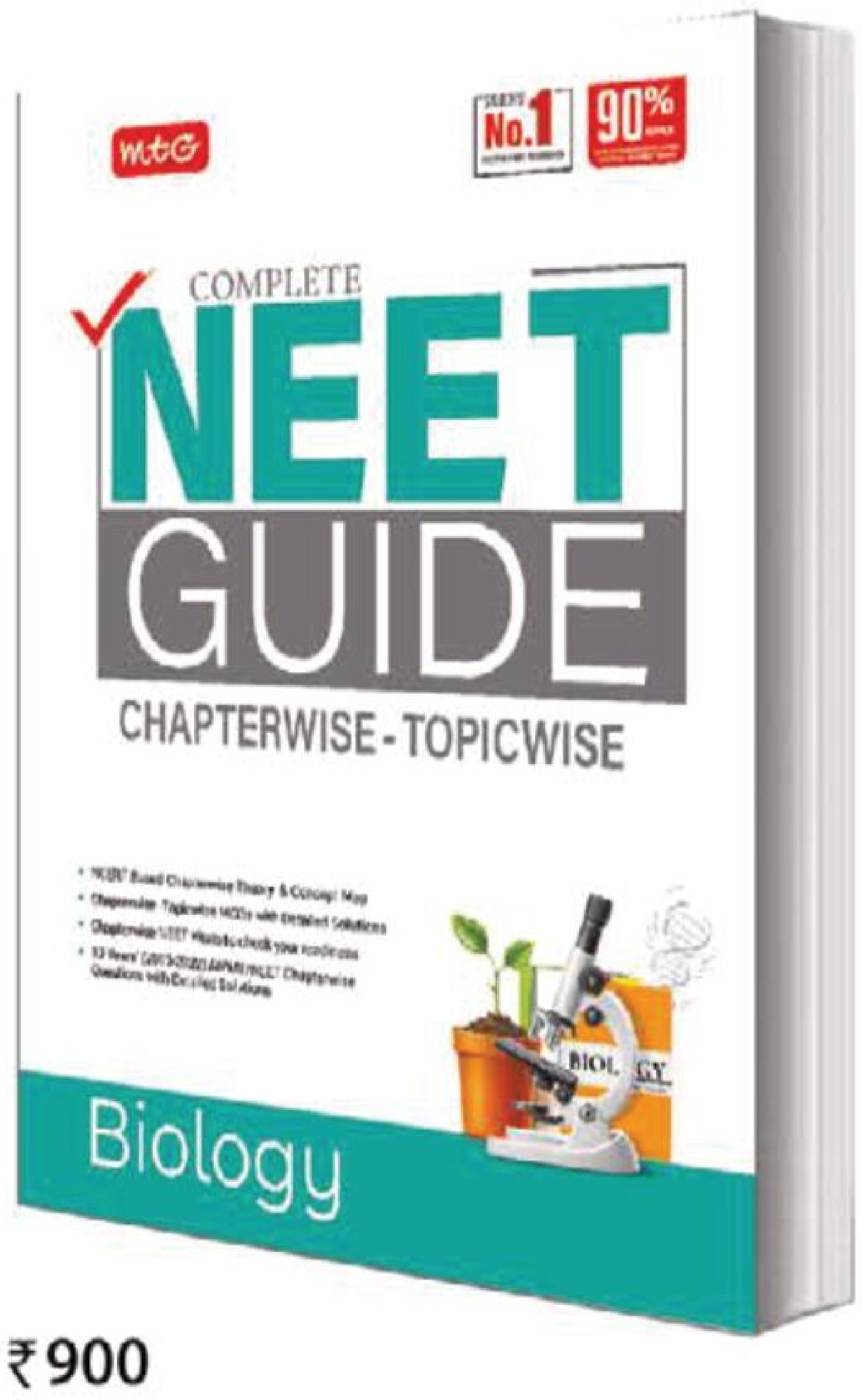

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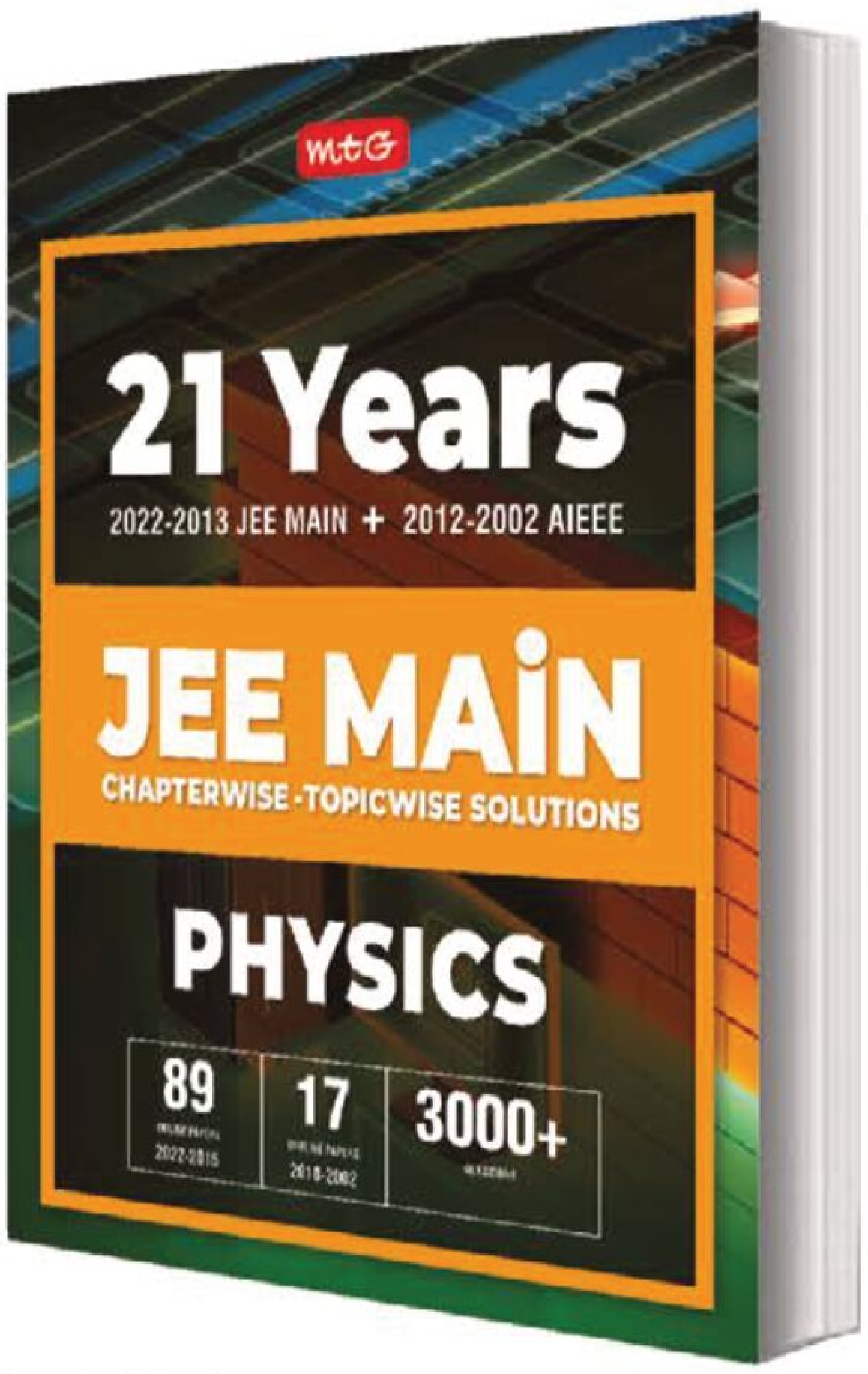
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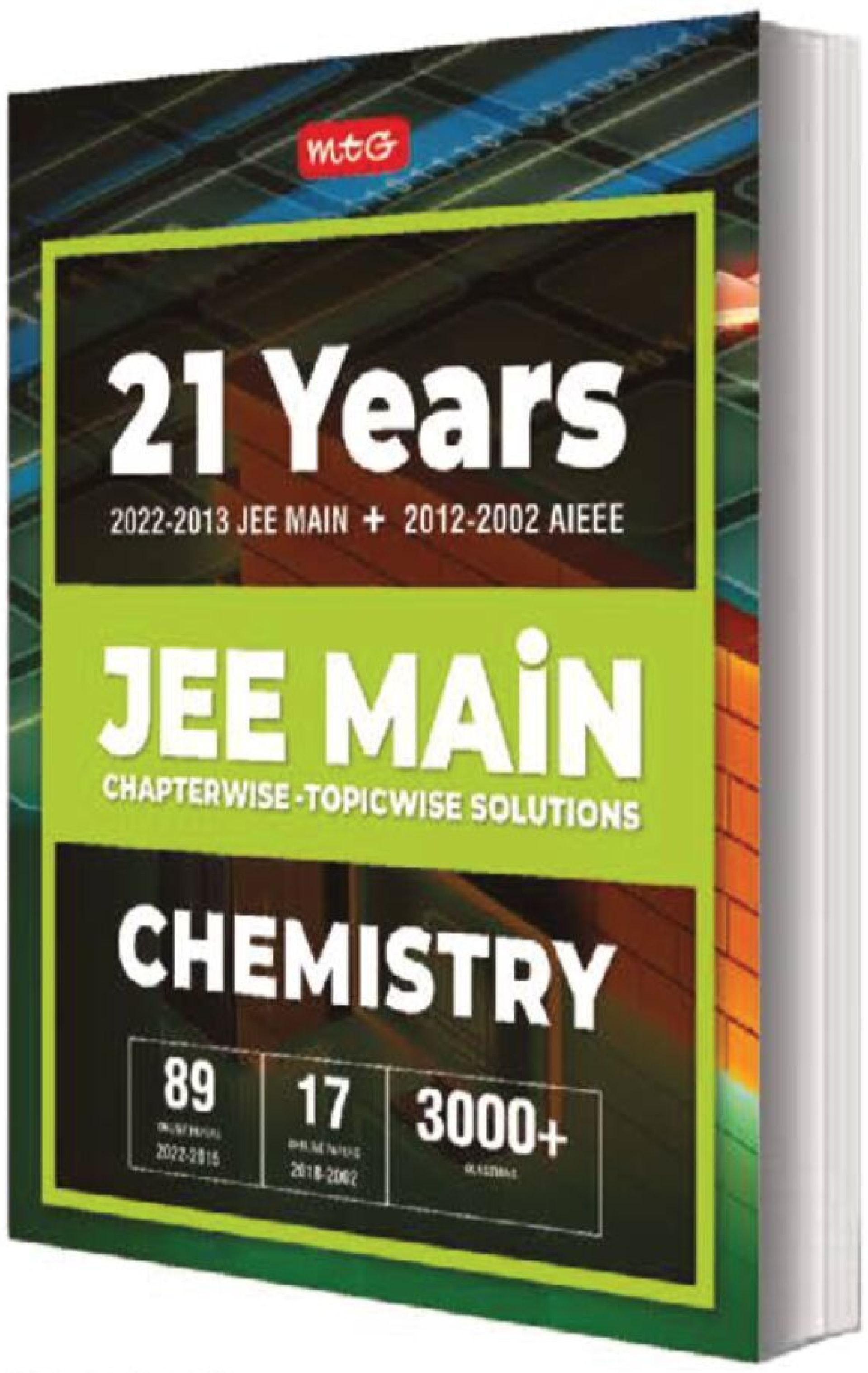
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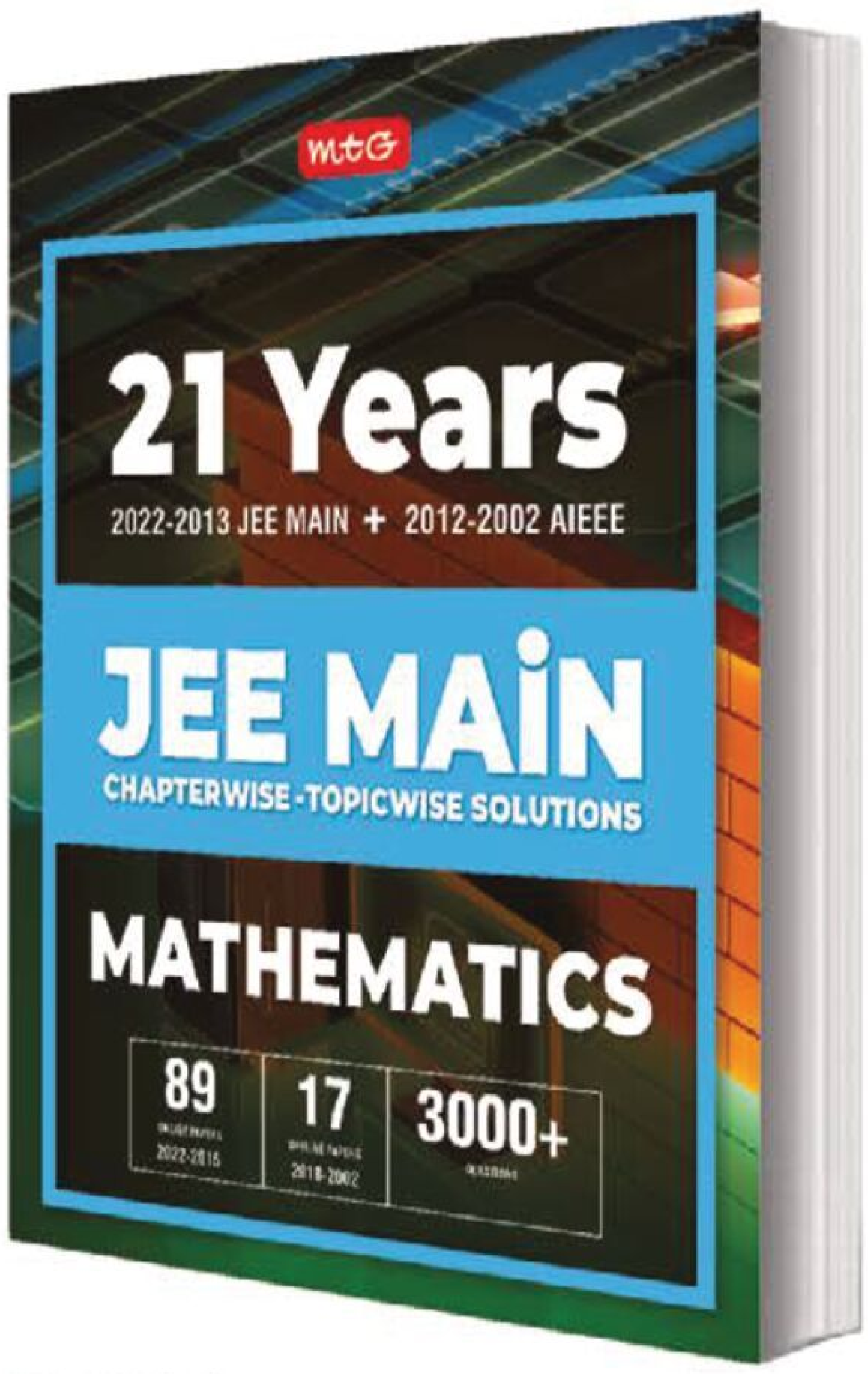
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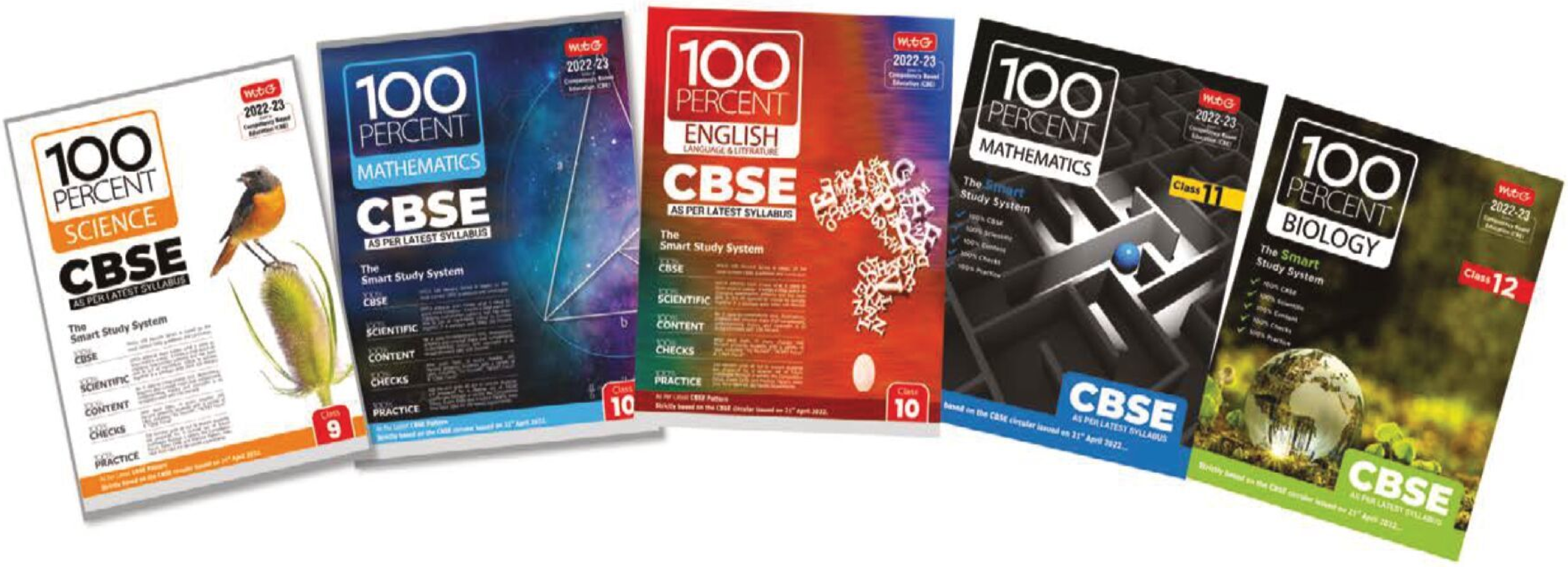

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